MAASTRICHTIAN TO EARLY EOCENE CALCAREOUS NANNOFOSSILS FROM EGYPT

ALAAELDIN MOHAMED ABDEL BAKY
B.Sc. 1980

A Thesis submitted

for

The degree of Doctor of Philosophy

UNIVERSITY COLLEGE LONDON

1988

CONTENTS

FIGURES

TABLES

ACKNOWLEDGEMENTS

First of all I want to thank my father for his great support during this study.

I wish to acknowledge sincerely Dr. A. Lord for supervising the work and giving full encouragement during the progress of the study.

The financial support from the British Council during the years 1983/84 and 1984/85 for the advancement of Pure Research is much appreciated. I gratefully acknowledge the financial support for the year 1985/86, typing and binding facilities from Paleoservices Ltd.

Special thanks to Dr. V. L. Roveda (Chairman of Paleoservices Ltd.), Mr. S. Fahmy (Managing Director of Paleoservices Egypt Ltd) and Mr. A. D. King (Managing Director of Paleoservices London) for their co-operation and continuous encouragement. I wish to express my thanks to the following persons: "it would be impossible to mention all of them" Geologist Mr. H. Fouda (GUPCO) who gave me valuable help with the photographs and the field work, Geologist Mr. A. Salah (Core Lab Co.) for providing me with Wadi Tarfa samples and field assistance (August 1983), Dr. M. Haggag (Ain Shams University, Cairo) for providing me with Gebel Atshan samples, Geologist N. Enany (Belayim Oil Co.) for his guidance during my field trip (September 1984), my colleague L. Gallagher (Research Student, U.C.L.) for reviewing the manuscript and the technical staff of the Post-graduate Unit of Micropalaeontology (University College London) Dr. A. Rees and Mr. M. Gay.

A special word of gratitude to Mrs. Ann Hardy (Paleoservices Ltd) for patiently carrying out the typing of this thesis and Mrs. Judy Andrews (Paleoservices Ltd) for the careful drawing of the diagrams.

ABSTRACT

A study of calcareous nannofossils from the Maastrichtian-Early Eocene from Egypt has resulted in the recognition of four Maastrichtian and seven Early Tertiary biostratigraphic zones. These nannoplankton zones are based upon local ranges and compared with the zones proposed by Martini (1971), Sissingh (1977), Verbeek (1977) and Romein (1979). A new zone, the Fasciculithus ragaae Zone is described and the Ellipsolithus macellus Zone and the Fasciculithus tympaniformis Zone are emended. Study of the vertical ranges of the species provided many markers (including the zonal markers) with distinctive first and/or last occurrence levels.

The uppermost Maastrichtian and Lower Danian are missing in the study sections. There is no change in the lithology at the Cretaceous-Tertiary boundary as observed in the Esh Mellaha area, but biostratigraphic evidence shows that there is a time gap and the boundary missing. This boundary is, however, marked by a conglomerate band at Gebel Um El Ghanayem, a thin bed of black non-calcareous shale at Gebel Duwi and a change in the lithology from chalky limestone (upper part of Sudr Chalk Formation) of Maastrichtian age to shale (lower part of Esna Shale Formation) of Early Palaeocene age at Wadi Tarfa. No continuous Cretaceous-Tertiary boundary sequence was analysed. The palaeoenvironment during the Maastrichtian-Early Eocene according to the nannofossil assemblages, was a warm open marine inner to outer shelf, although the absence of late Maastrichtian and early Danian age sediments limits observation and comment.

One hundred and sixty five species have been identified. Descriptions, remarks and figures as well as schematic drawings of many species are presented. A new family RHOMBOASTERACEAE, a new genus Diadochiastozygus, five new species Fasciculithus ragaae, F. gelelii, Discoaster atefii, D. duwiensis and D. amrii are described. New combinations for Bomolithus megastypus, B. cantabriae, Diadochiastozygus imbriei, D. saepes, D. eosaepes, Tranolithus tarboulensis, Vekshinella dorfii and V. compacta are proposed. The evolution of some Cretaceous and Early Tertiary nannofloral groups is discussed and a link between the Bomolithus and Discoaster groups proposed.

CHAPTER I

INTRODUCTION

Historical review of calcareous nannofossil research

Coccoliths are the calcified plates forming the outer cover of certain group of marine, unicellular, autotrophic, biflagellate golden brown algae. In the recent representatives of this group these coccoliths envelop the cell to form the coccosphere. The skeletal elements of the coccospheres and other certain fossil groups commonly associated with them (e.g. Micula, Discoaster) of which a coccosphere is not reported from the stratigraphic record or they do not have a living representatives (due to their limited stratigraphic distribution) are known as calcareous nannofossils.

Calcareous nannofossils have been known for over a century, but only in the last 2 decades they have become widely used as stratigraphic indicators.

Ehrenberg (1836) first observed the coccoliths in a sample of chalk. He figured both discoasters and coccoliths but termed the coccoliths "Morpholite" and some discoasters "Kalkerdige crystalldrusen", indicating that he did not consider them of organic origin. The term "Coccolith" was proposed by Huxley (1858).

It became generally accepted that coccoliths were skeletal elements formed by some sort of organism, and Huxley became convinced that coccoliths were produced by a protoplasmic slime which covered the floor of the oceans.

Wallich (1861) established that coccoliths form coccospheres and are the tests of free floating organisms.

Studies of living coccolithophores did not start until the early part of this century, and expanded in the past twenty years with the advent of electron microscopy as an aid in identification. Discoasters were first described in detail, by Tan (1927).

The modern era of investigation of calcareous nannofossils which include fossil coccoliths as biostratigraphic indicators was initiated by Bramlette and Riedel (1954).

The greatest aid to the development of a refined biochronologic scale using nannofossils was supplied by the availability of cores taken from the Deep Sea Drilling Project (D.S.D.P.) which began in 1968.

The Palaeogene calcareous nannofossil biostratigraphy is discussed in detail in Hay et al. (1967), Hay and Mohler (1967), Bramlette and Wilcoxon (1967), Martini (1971), Bukry (1973a), Romein (1979), Aubry (1983), Theodoridis (1984) and Perch-Nielsen (1985).

Upper Cretaceous nannofossil biostratigraphy is discussed by Gartner (1968), Bukry (1969), Thierstein (1976), Sissingh (1977), Verbeek (1977), Smith (1981), Crux (1982) and Perch-Nielsen (1985).

Purpose of investigation:

Most of the calcareous nannofossils of the Late Cretaceous-Early Tertiary are well illustrated in recent literature with the light microscope and the scanning electron microscope, which make easy to study them. The Upper Cretaceous-Lower Tertiary of Egypt is chosen because of the abundant occurrence and the high diversity of the calcareous nannofossils, also relatively few studies have been made on nannofossils across the Cretaceous-Tertiary boundary in Egypt, mainly with the light microscope and few with the scanning electron microscope. This work is designed to:

1) Determine the distribution of calcareous nannofossils between the Maastrichtian and the Eocene in Egypt.

2) To assign the strata to international chronostratigraphic units, using the calcareous nannofossils

The Cretaceous-Tertiary boundary:

The Cretaceous-Tertiary boundary event is marked by the complete extinction of many Mesozoic species. Many groups of organisms, particularly calcareous plankton in the oceans and the large reptiles on land, suffered accelerated extinction because of various environmental stresses. Many geologists believe that a large body impact occurred at the end of the Cretaceous causing mass mortality and changes of the chemistry, temperatures and planktonic fertility in the ocean took place in the first few thousand years of the Tertiary.

Since the pioneer study of Bramlette and Martini (1964), nannofossil workers have believed that the Cretaceous-Tertiary boundary is marked by the nearly complete extinction of Mesozoic coccolith-bearing phytoplankton. This interval has been discussed extensively by many nannofossil specialists (Worseley (1974), Romein (1977), Thierstein and Okada (1979), Thierstein (1982), etc). Romein (1977) described a continuous section across the Cretaceous-Tertiary boundary discovered by Smit (1977) called Gredero section, Caravaca, S.E. Spain. Romein mentioned that at this section there is no abrupt extinction of the Cretaceous species, they disappeared gradually from the record in the lowermost Danian.

Perch-Nielsen et al. (1982) studied the Cretaceous-Tertiary boundary sections from different localities in the world (including the El Kef section, Tunisia) by a combination of calcareous nannofossils and planktonic foraminifera biostratigraphy and isotope stratigraphy (carbon and oxygen isotopes). They concluded that the catastrophic event at the Cretaceous-Tertiary boundary did not result in the extinction of the Maastrichtian calcareous nannoplankton. They considered that the Maastrichtian nannofossils in the Lowest Tertiary sediments actually survived the Cretaceous-Tertiary boundary event and became extinct some tens of thousands of years after the mass mortality of other organisms at the boundary. This is due to environmental stress rather than as a result of a catastrophic extinction coinciding with the Cretaceous-Tertiary boundary. In my sections, the absence of a continuous section across the boundary (at least from the top of N. frequens Zone to the lowermost part of Chiasmolithus danicus Zone is missing) make it impossible to test the above mentioned opinions by Romein (1979) and Perch-Nielsen *et al.* (1982). Although *Placozygus sigmoides*, *Thoracosphaera operculata*, *Markalius astroporus*, *Braarudospharea bigelowi* which are known to continue from the Cretaceous into the Tertiary are detected here and are considered to have survived the Cretaceous-Tertiary boundary event as they show persistent presence (except *B. bigelowi*) in the Palaeocene and the Lower Eocene assemblages. *Micula staurophora*, *Arkhangelskiella cymbiformis*, *Eifellithus turriseiffeli*, *Watznaueria barnesae* and *Prediscosphaera cretacea cretacea* are very rare in the Danian and are considered to be reworked. The absence of most Cretaceous species in the Danian is due to submarine erosion at the end of the Cretaceous and probably the early Danian.

Geological setting and Late Cretaceous-Early Tertiary history of Egypt

Egypt occupies the northeastern most part of the great African craton, and a great part of the Arabo-Nubian massif is well represented.

The Arabo-Nubian massif in Egypt consists of mainly Pre-Cambrian igneous and metamorphic rocks, which have been subjected to rather intensive tectonics and form mountain ridges well represented in the Eastern Desert and South of Sinai.

Tectonically Egypt was divided by Said (1962) into four geological divisions or provinces.

1. The Arabo-Nubian massif

It consists of ridges of basement rocks, widespread over the most of the Eastern Desert area and South of Sinai.

2. The Stable Shelf

This zone is characterised by relatively thin sedimentary deposits, it includes the areas surrounding the Arabo-Nubian massif. This area was less affected by the tectonic movements than the unstable shelf.

3. Unstable Shelf

This shelf covers most of the northern part of Egypt. The boundary between the unstable and the stable shelf can be plotted close to the south of a line between Suez, Cairo and the Baharia Oasis. This area has a relatively thick marine sedimentary sequence and is intensively folded and faulted.

4. The Gulf of Suez taphrogeosyncline

The term taphrogeosyncline was applied by Said (1962) who described the area as an active zone of subsidence and accumulation of sediments from the Palaeozoic to the present day.

Many geologists today consider the Gulf of Suez a part of the great Eastern African rift valley. The Gulf of Suez depression represents an intensively faulted area, with a large number of blocks with different dimensions. The faulting movements were active during the Late Cretaceous and Early Cenozoic and eventually, with great intensity during the Oligocene and later.

Upper Cretaceous-Lower Tertiary rocks cover a great part of Egypt. The transgression of the Tethys over Egypt in the Late Cretaceous started early in the Cenomanian, when much of the country was flooded by marine water. The stable shelf was affected by a great deformation during this transgression. This transgression caused the shifting of depositional environments progressively towards the south.

In the Eastern Desert, the Upper Cretaceous-Lower Tertiary formations crop out on both sides of the basement rocks of the Red Sea. On the western side of the basement rocks, the Cretaceous-Tertiary sediments extend into the Western Desert across the Nile river. On the eastern side of the basement ridge near Quesir, Upper Cretaceous, Palaeocene and Lower Eocene beds form elongated basins within the dissected crystalline ridge.

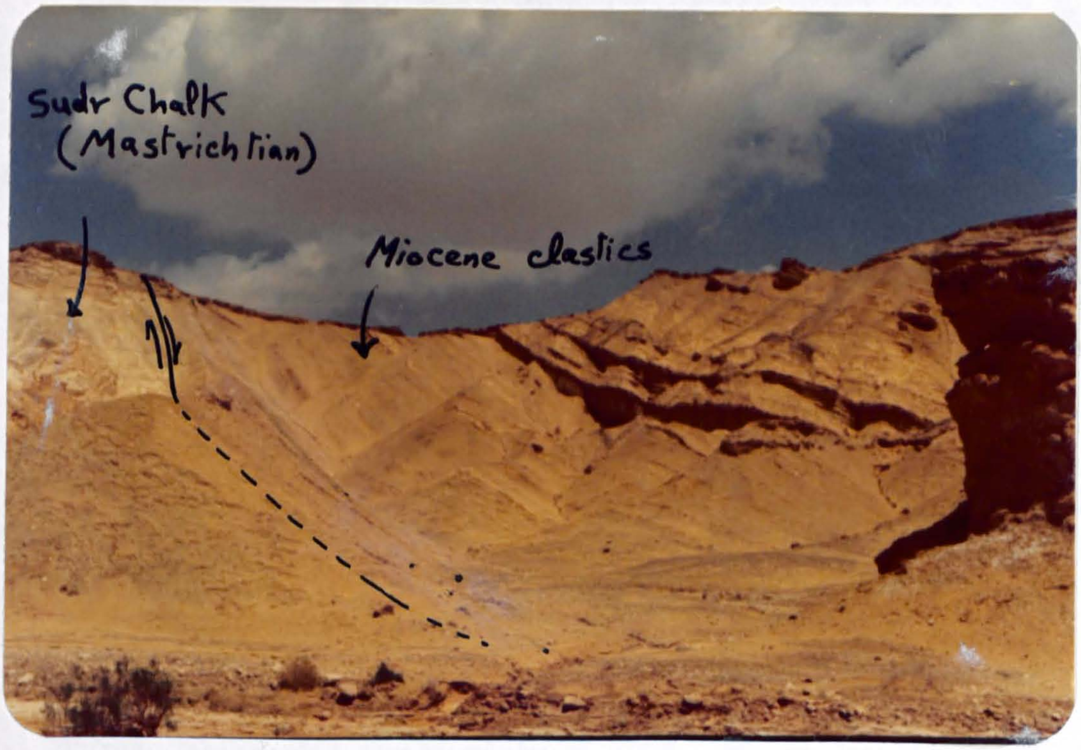


Fig.1 - Normal fault at Hammam Faraun (north eastern part of Gulf of Suez)

Fig.2 - Basement rocks of Esh Mellaha (at the South Western Coast of Gulf of Suez) capped with Miocene sediments

Field Work:

The Upper Cretaceous - Lower Tertiary succession from selected localities in Egypt was sampled during August 1983 and September 1984. During the first field trip in 1983 three sections were measured and sampled from Esh Mellaha range. These sections are:-

1) Gebel Tarbouli section at the northern most tip of Esh El Mellaha range

2) Wadi Abu Had at the southeast of the first section by 22 km.

3) Wadi Mellaha section to the southeast of the first section by 45 km.

During the second field trip in 1984, two sections were measured and sampled from Quseir area on the Red Sea Coast and from Kharga Oasis, Western Desert. These sections are:-

1) Gebel Duwi section, Quseir area

2) Gebel Um El Ghanayem, Kharga Oasis

Two other sections are included in my study. Gebel Atshan section, Quseir area and Wadi Tarfa section at the south of Galala plateau, Eastern Desert.

To fulfill the aim of this thesis the lithologic units representing the Upper Cretaceous-Lower Tertiary in the investigated areas were studied carefully in the field and closely spaced samples (sampling interval between 0.5 and 4 metres) were collected. The sampling interval was not constant in any of the investigated sections as intensive sampling was carried out for the more soft successions, highly calcareous sediments, at sharp changes in the lithology and for particular horizons or levels, e.g. at the Cretaceous-Tertiary boundary and at the Danian of Gebel Duwi (where sampling interval was 0.5 metre) to try to detect the ancestors of many Early Tertiary groups which rapidly appeared at that time (e.g. Fasciculithus, Sphenolithus and Bomolithus). The total number of samples collected and examined was 439. The sections were measured in the field by an Abun level, Brunton compass and meter. A hammer and chisel were used to clean and remove the weathered surface to expose a fresh unweathered surface before taking the sample. Each sample of about 5 cm^3 was stored in sealed small plastic bags during the period of the field work.

Techniques and methods of preparation:

The methods of preparation for nannofossil study used during this work are those followed in the Postgraduate Unit of Micropalaeontology, University College London and described by Edwards (1963) and Hay (1965). These methods are:

A. Soaked smear slides :

The basic method for preparing smear slides consists simply of crushing a small piece of sediment onto a glass slide and mixing it with water before applying a cover slip. the smears slide technique adopted here involved preliminary soaking of the sample in Calgon to help disperse the clay minerals. This helps to separate the coccoliths from the rock debris and makes it easy to observe and identify the nannofossils in the light microscope.

In this method:

1 - A small piece of the sample (about 1 cm^3) was cleaned by scraping the surface to avoid any contamination.

2 - The cleaned sample was crushed and placed in 100 ml beakers.

3 - Calgon (sodium hexametaphosphate solution) was added, then the solution was stirred with a glass rod and left for up to 12 hours.

4 - Then, the solution was stirred again for 60 seconds, left to stand for about 15 seconds (to separate the coccoliths from large rock debris) and then the solution in the upper half of the beaker was poured into a second smaller beaker.

5 - The solution in the second beaker was diluted with distilled water, stirred, and pipetted onto a slide (until the surface of the slide was completely covered). The solution was dried on a hot plate, then covered with Canada balsam with Xylene and a cover slip.

B. Centrifuging technique :

The centrifuging method is more complicated than the previous one, but the ratio of the dirt to nannofossils is lower, and this makes detailed study easier. An ultrasonic vibration was used for up to 10 minutes to assist disaggregation of some samples with a high clay content. In this method the basic techniques were:

1 - The samples were soaked in Calgon for a few hours.

2 - Then the samples were stirred with a glass rod and poured into centrifuge tubes.

3 - Centrifuging the solution once at 350 rpm for 15 seconds and stopping the centrifuge quickly.

4 - Then, the residue was mixed with distilled water and centrifuged at 850 rpm for 60 seconds and allowed to stop on its own.

5 - The residue was again mixed with distilled water and the last process was repeated until the supernatant was clear (the process was carried out a maximum of two times).

6 - The residue was diluted and pipetted onto a slide.

7 - After pipetting the solution onto a slide, the solution was dried on a hot plate, then covered with Canada balsam with Xylene and a cover slip. Then the slide was examined in the light microscope.

Methods of investigation:

The investigation of the nannofossil assemblages has been carried out with the aid of both the light microscope and the scanning electron microscope.

A. Light microscope techniques :

For routine studies of nannofossil assemblages and specimens the light microscope (Zeiss photomicroscope II) is the most suitable instrument. This microscope is equipped with a micrometer stage, cross nicols and phase contrast equipment. To this microscope is attached photomicrographic equipment which permitted photography of the nannofossil species in the course of examination. Phase contrast and cross-polarised light were used to obtained the maximum amount of information. Light microscope slides were used as a basis for identifying the nannofossils, with the purpose of studing the occurrence, distribution and abundance of each species from each sample. So, permanant mounts were made for all the samples for light microscope studies. The material used as a permanent mount was Canada balsam with Xylene. I have tried "Glycerine" as a mounting medium because Canada balsam is expensive and harmful to health, but it was not effective as a permanant mount unless the edges of the slides are carefully sealed. Probably it will be useful, for rapid slide preparation and observation.

B. Scanning electron microscope techniques :

A few drops of the nannofossil solution were spread over a 13mm diameter cover slip which was then gently dried in a warm oven. In order to get a good distribution of nannofossils on the cover slip, the solution must be relatively dilute. If the solution containing the nannofossils is dense, then the nannofossils will be concentrated in patches and it will be hard to study and to observe the fine ultrastructures of the species. The cover slip with a dispersal of nannofossils was then stuck to an aluminium SEM stub using colloidal silver as a conductive adhesive to allow the transmission of electrons. The surface of the stub was then coated with a thin layer of gold to make the surface of the specimens conductive. Photographs of the species from different views and magnifications were taken using the SEM (which was operated by me).

Counting techniques and data presentation:

The relative abundance of every species and the state of preservation of the assemblage for every slide were represented in the range charts by a special symbol. Counts of relative abundance of the species present in each slide were made in 300 fields of view of the light microscope at a magnification of 2 x 40 x 10.

1 - Preservation symbols (scale) :

G = Good (the specimens are not or slightly affected by dissolution and/or overgrowth)
M = Moderate (less than half of the specimens are affected by dissolution and/or overgrowth)
P = Poor (most parts of the specimens are affected by dissolution and/or overgrowth)
E = etched assemblage
O = overgrowth assemblages

2 - Relative abundance scale :

1, 2, 3, 4 = very rare

● = rare/5-20 specimens per (300) fields of view

● = common/21-99 specimens per (300) fields of view

● = very common/100-300 specimens per (300) fields of view

● = abundant/more than 1 specimen in each field of view

CHAPTER II

SAMPLED AREAS

1. Kharga area

The oasis of Kharga forms a depression lying about 200 km west of the Nile between latitude 24° and 26° north. The geology of the area has been studied by many geologists. Zittle (1883) and Ball (1900) were the first to study the stratigraphy and geology of the Kharga area. Awad (1964) described a number of biostratigraphic zones based on megafossils (Hermina 1968, p.7). Awad and Ghobrial (1965) gave a detailed classification of the sedimentary succession in the area. In this classification the Upper Cretaceous-Lower Tertiary was represented by: from top to bottom:

Thebes Formation	(Ypresian)
Esna Shale	(Upper Danian?-Landanian)
Tarawan Chalk	(Danian)
Dakhla Shale	(Maastrichtian-Danian)

Structurally, Said (1962) considered the area as a part of the stable shelf which he considered as mildly folded. Ghobrial (1967) mentioned two tectonic movements which affected this area, a pre-Maastrichtian one which caused the formation of the Kharga basin and the second is a post Lower Eocene movement which caused the predominant folding and faulting in the area.

The most recent biostratigraphic work in the area was done by Faris (1985). He studied the Upper Cretaceous-Lower Tertiary from Ghanima and Ain Amur sections on the basis of the planktonic and large benthic foraminifer and the calcareous nannofossils. He found the latest Maastrichtian and the early Danian fauna and flora to be missing and considered that the absence of Micula prinsii Zone in both sections indicate the absence of the latest Maastrichtian. He mentioned also the absence of Markalius inversus (= M. astroporus, this work) and Cruciplacolithus tenuis Zones at Ghanima and the absence of M.

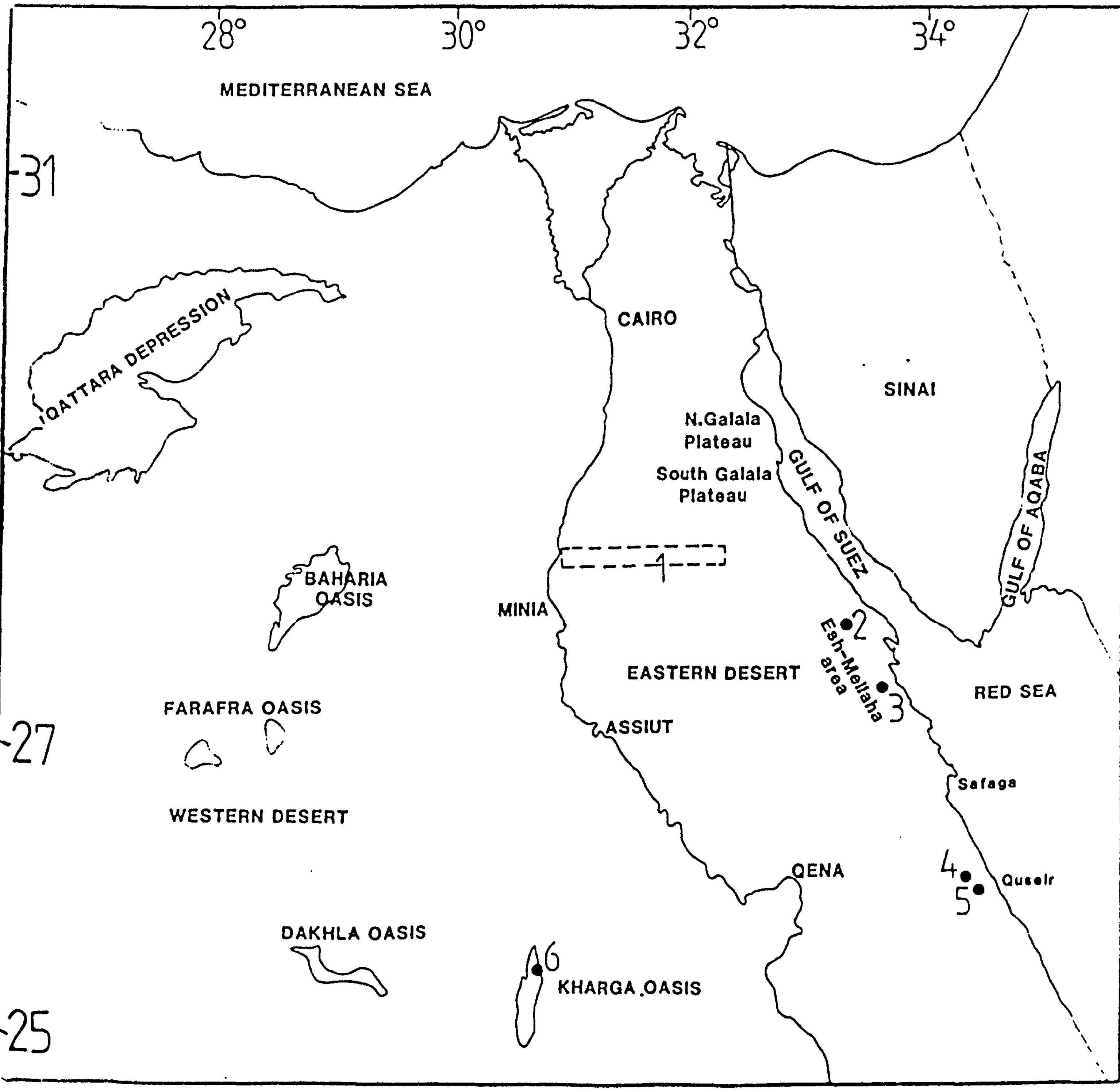


Fig. 18 LOCATION MAP FOR THE STUDIED AREAS

1- WADI TARFA SECTION
2- GEBEL TARBOULI SECTION
3- WADI MELLAHA SECTION
4- GEBEL DUWI SECTION
5- GEBEL ATSHAN SECTION
6- GEBEL UM EL GHANAYEM SECTION

inversus and the lower part of C. tenuis Zones at Ain Amur. He observed that there is no lithologic change between the Maastrichtian and the Danian in the area where the same shale with or without a phosphatic band was found below and above the Cretaceous-Tertiary boundary in the Kharga sections. During the present work at Gebel Um El Ghanayem, Kharga, the Nephrolithus frequens Zone is not found and the Cretaceous-Tertiary boundary is marked by the presence of a conglomeratic band indicating an unconformity at the above mentioned boundary.

Gebel Um El Ghanayem section (Fig. 19)

Gebel Um El Ghanayem is situated at latitude 25° 28'N and longitude 30° 48'E about 20 km east of the Kharga depression. The oldest rocks exposed in the area are the Nubia group which consist of cross-bedded sandstone and shale of probable Pre-Maastrichtian age. The samples were collected from these formations in stratigraphic order:

1. Dakhla Shale : (+71m) the succession of strata met are, from base to top:

    - Shale, black to dark grey, highly fractured with gypsum veins, non-calcareous,forming a gentle slope (22m).

    - Limestone, reddish brown, fine grained, hard, packed with Exogyra overwegi, forming a cliff (4m).

    - Shale, black to dark grey, occasionally gypsiferous, non-calcareous, forming a gentle slope (23m).

    - Sandstone, conglomeratic, slightly calcareous with shale pebbles (reworked), yellowish grey (1m).

Fig.3 - General view of Gebel Um El Ghanayem

Fig.4 - Top of Limestone bed (Dakhla Shale Formation) packed with Exogyra overwegi at Gebel Um El Ghanayem section

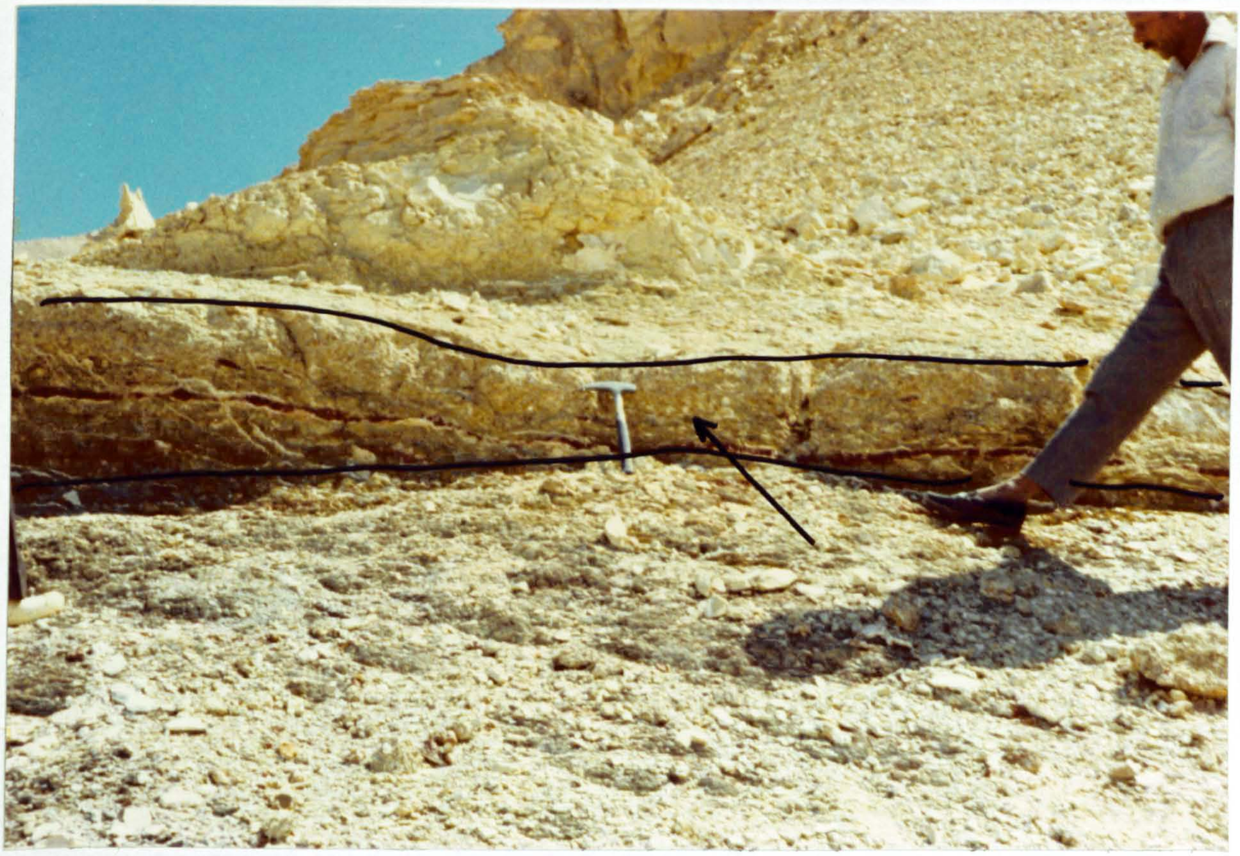


Fig.5 - Conglomeratic band at the Cretaceous-Tertiary boundary at Gebel Um El Ghanayem section

Fig.6 - Upper part of Dakhla Shale overlain by Tarawan Chalk at Gebel Um El Ghanayem section

- Shale, light grey to dark grey, gypsiferous, highly calcareous, forming a gentle slope, (20m).

2. Tarawan Chalk : (8m)

- Limestone, yellowish white, moderately hard, chalky, marly at top and bottom, fractured with gypsum along fractures, forming a cliff.

3. Esna Shale : (+21m)

- Shale, light grey, gypsiferous, calcareous, non-calcareous at top, forming a gentle slope.

2. Quseir area

This area is along the Red Sea. It extends 50 km to the north and 30 km to the south of Quseir city with an average breadth of about 20 km. The Upper Cretaceous-Lower Tertiary rocks in the area form isolated sedimentary bodies mostly in the form of faulted synclines (Youssef 1957). Gebel Duwi and Gebel Atshan are among the main sedimentary bodies representing the Upper Cretaceous-Lower Tertiary in this area. The geology of Quseir area has been discussed by Youssef (1957) who defined and described the formations composing the Upper Cretaceous of Quseir area. Said (1962) in the Quseir-Safaga District, regarded the shales overlying the Duwi Formation as Dakhla Shale and considered them of Maastrichtian and Danian age. Also he regarded the thick unit of laminated shales overlying the Chalk (now Tarawan Chalk) as Esna Shale and referred them to the Upper Palaeocene. Krasheninnikov and Abd El Razik (1969) dealt with the stratigraphy of the Upper Cretaceous and Palaeogene sediments of two neighbouring sections, Gebel Duwi and Gebel Anz, Quseir area. They concluded that the Danian which is usually represented by a few metres in Egypt is almost complete in Gebel Duwi and the Upper Cretaceous-Palaeogene sediments are continuous while in Gebel Anz the Cretaceous-Tertiary boundary is marked by a big hiatus that causes four zones to be absent (*Eoglobigerina eobulloides*, *Globigerina triloculinoides* - *G.*

pseudobulloides, Acarina uncinata and Globorotalia angulata Zones). Also, they found the thickness of zones and formations in Gebel Anz to be highly reduced in comparison with the sequence in Gebel Duwi, which reflects the graben structure of the Red Sea and the Gulf of Suez. El Dawoody and Barakat (1973) examined the Upper Cretaceous-Lower Tertiary rocks from Gebel Duwi. The calcareous nannofossils and the planktonic foraminifera were used for the biostratigraphic zonation of the succession. They found the M. astroporus Zone (the lowest nannofossil zone in the Tertiary) overlying the A. cymbiformis Zone and thus the disconformity at the top of the Maastrichtian indicates a short break of time in Gebel Duwi as compared with other localities in Egypt. Faris (1984) studied the calcareous nannofossils and the planktonic foraminifera of the Late Cretaceous-Early Tertiary of Gebel Duwi. He mentioned that there is no lithologic change near the Cretaceous-Tertiary boundary, but a barren dark grey shale horizon is present. This shale bed is found during this work as well. He found also in his section that NP1, NP2 and the lower part of NP3 Zone were missing. The absence of these zones is confirmed in the present study.

2-1 Gebel Duwi section (Fig. 20)

Gebel Duwi is located about 13 km west (and extending northwestward) of Quseir city. The oldest sedimentary formation, the Nubia sandstone rests unconformably over the basement complex. The Cretaceous-Lower Tertiary succession is as follows from bottom to top:

Nubia Formation
Quseir variegated shales
Tarawan Chalk
Esna Shale
Thebes Formation

The samples were collected from these formations in stratigraphic order:

Fig.7 - Marls of Dakhla Formation form a wall at Gebel Duwi section

Fig.8 - The contact between Tarawan Chalk and Esna Shale at Gebel Duwi

Dakhla Shale : (+116m)

The strata met are:

- Marl, yellowish white to grey white, moderately hard, gypsiferous (24.5m).

- Shale, dark grey to black, non-calcareous (1.5m).

- Marl, yellowish white to grey white, moderately hard, ferrigenous, gypsiferous (90m).

Tarawan Chalk : (47m)

Limestone, yellowish-white, hard to moderately hard argillaceous, chalky, ferrigenous.

Esna Shale : (+42m)

Shale, light grey to yellowish grey, forming a gentle slope.

2-2 Gebel Atshan section (Fig. 21)

Gebel Atshan is located about 8km west-south west of Quseir city. The succession of rocks is not different from that in Gebel Duwi. The samples were collected from these rock units in stratigraphic order.

Dakhla Shale : (+ 150m)

Shale, yellowish grey to dark grey, intercalated with marl, yellowish brown, gypsiferous, ferrigenous.

Tarawàn Chalk : (22m)

Limestone, yellowish white, chalky, argillaceous, gypsiferous, ferrigenous, forming a cliff.

Esna Shale : (+ 81m)

Marl, yellowish white to grey white, ferrigenous.

3. Esh Mellaha area

Esh Mellaha range described by Said (1962) as a ridge extending in a southeastern direction for over 80 km and its average breadth is 10-15 km. Esh Mellaha is divided into two parts:

1. The eastern ridge which is composed of igneous and metamorphic rocks forming high rugged peaks sometimes reaching 500m above sea level with patches of Miocene rocks on its eastern flanks.

2. The western ridge which is composed of Cretaceous and Eocene sedimentary rocks forming a line of scarps and attaining a height of nearly 300m above sea level.

Shafik and Stradner (1971) made the only study dealing with calcareous nannofossil for the Upper Cretaceous-Lower Tertiary of Esh Mellaha sediments. They investigated the planktonic foraminiferal contents and the calcareous nannofossils of the Tarawan Chalk (=Upper part of the Sudr Chalk in the present work) of Gebel Tarbouli and located the fossils they found within the vertical limits of Abathomphalus mayoroensis Zone. Lithraphidites quadratus was among the nannofossil assemblage in Tarawan Chalk but not N. frequens or M. murus (Late Maastrichtian forms). In addition, they gave a framework of the nannofossil assemblages of the early Tertiary from several sections cropping out along the western side of both the Gulf of Suez and the Red Sea. They found Marthasterites spineus Zone Shafik and Stradner 1971 (equal the upper part of the Discoaster multiradiatus Zone, this work) to be the oldest nannofossil zone in the Esna Shale of Esh Mellaha range, and the lower part of Esna Shale of Gebel Tarbouli belong to Marthasterites contortus Zone (NP10) (=Tribrachiatus contortus Zone). During the present work, the Nephrolithus frequens Zone, Lithraphides quadratus Zone, A.

cymbiromis Zone and the upper part of Q. trifidum Zone is found in the upper part of Sudr Chalk (is equivalent to Tarawan Chalk of Shafik and Stradner 1971) at Gebel Tarbouli (Fig. 22) also the upper part of N. frequens Zone plus NP4, NP5, NP9 Zones are found in the lower part of Esna Shale at Wadi Mellaha section (Fig. 23).

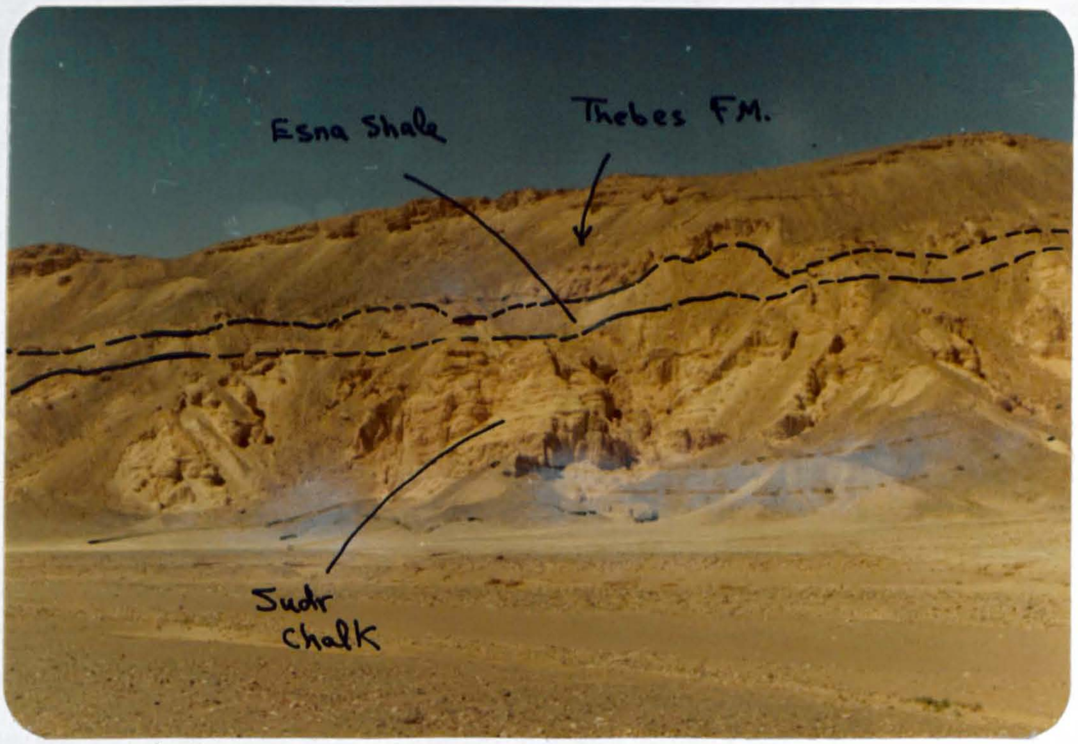


Fig. 9 - The Upper Cretaceous-Eocene sediments at Esh Mellaha area

Fig.10 - The base of the section at Esh Mellaha area

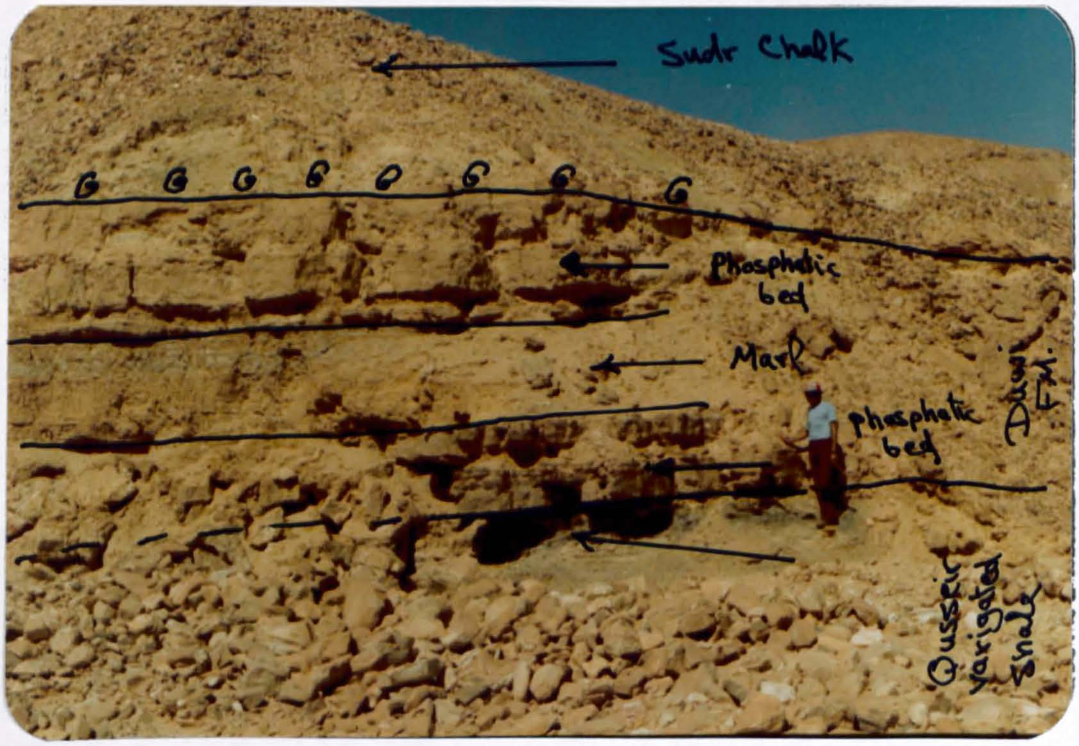


Fig.11 - Close up view of Sudr Chalk at Esh Mellaha area. The base of Sudr Chalk is packed with Ostrea vesicularis

Fig.12 - Close up view of the lower part of the Sudr Chalk which is packed with Ostrea vesicularis

3-1 Gebel Tarbouli section (Fig. 22)

Gebel Tarbouli is situated at latitude 27° 49'N and longitude 33° 11'E at the northern tip of Esh Mellaha range. The Cretaceous-Early Tertiary rocks are represented by these units from bottom to top:

Quseir variegated Shales
Duwi Formation
Sudr Chalk
Esna Shale
Thebes (cherty limestone) Formation

The basement complex is exposed and unconformably overlain by Nubia sandstone (of Devonian-Cenomanian) and Quseir variegated Shales respectively. The investigated samples were collected from these units in stratigraphic order:

1. Duwi Formation : (+ 3m)

   Phosphate, brownish on fresh surface, hard, fossiliferous (shark teeth) with thin chert band at the base.

2. Sudr Chalk : (41m)

   The strata met are:

   - Marl, yellowish white on weathered surface, greyish white on fresh surface, moderately hard, gypsiferous, ferrigenous (8m).

   - Limestone, yellowish white on weathered surface, pale white on fresh surface, chalky, argillaceous, fossiliferous contains <u>Ostrea vesicularis</u> (33m).

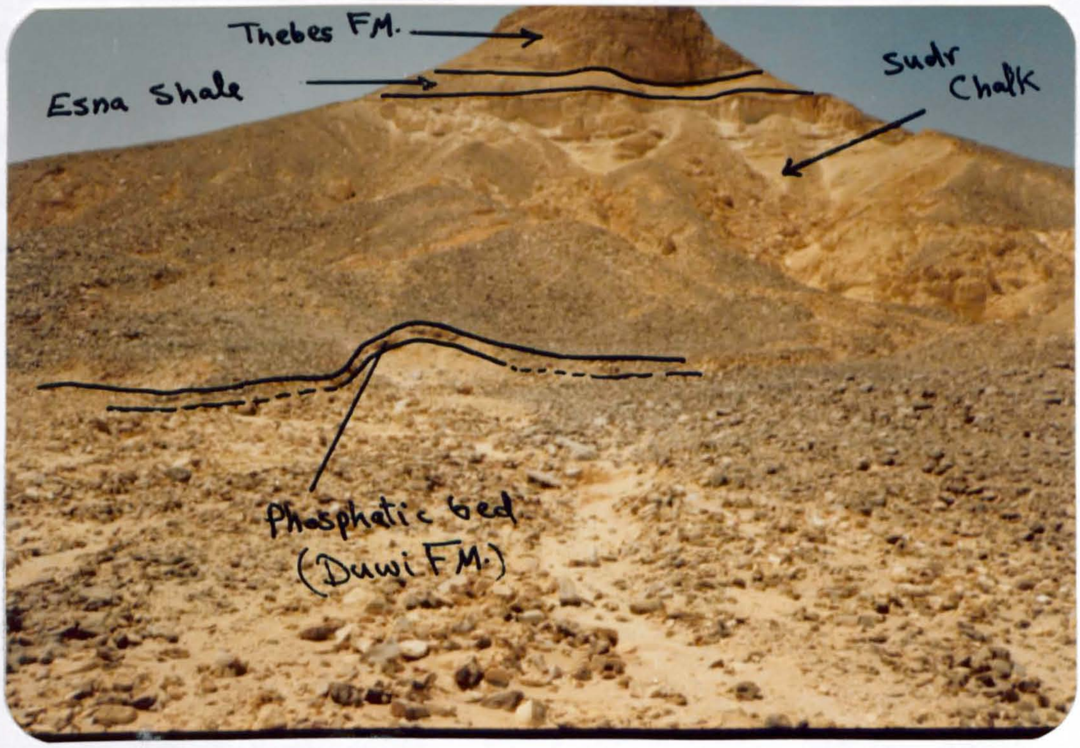


Fig.13 - The Upper Cretaceous-Eocene succession at Gebel Tarbouli

3. Esna Shale : (+ 13.5m)

Shale, greenish grey, moderately hard, highly calcareous, gypsiferous, with iron staining on bedding planes.

3-2 Wadi Mellaha section (Fig. 23)

Wadi Mellaha section is located at latitude 27° 32' 30" N and 33° 27'E almost 50 km south east of Gebel Tarbouli section. The succession of rocks is not different from that at the first section. The samples were collected from these rock units in stratigraphic order.

1. Duwi Formation : (+ 2.7m)

Phosphate, yellowish brown, hard, underlain by chert band, forming a cliff.

2. Sudr Chalk : (56m)

The strata met are:

- Shale, greenish grey, soft, ferrigenous, gypsiferous, forming a gentle slope (12m).

- Marl, yellowish white on weathered surface, greyish white on fresh surface, fossiliferous contains <u>ostrea</u> <u>vesicularis</u>, cracks filled with gypsum (13m).

- Limestone, yellowish white to grey white, chalky, moderately hard, fossiliferous (shell fragments), vertical and horizontal veins filled with gypsum, forming a cliff (31m).

3. Esna Shale : (+ 29m)

Shale, greenish grey, soft, cracks filled with gypsum, ferrigenous, forming a gentle slope, intercalated with thin limestone bed (at the base), pale brown, hard, forming a cliff (1m).

4. <u>Wadi Tarfa area</u>

The Upper Cretaceous-Palaeogene rocks are exposed in many places in the area. Wadi Tarfa is located between 28° 23' and 28° 26'N and 30° 52' and 32° 16'E, east of the Red Sea South of El Galala El Qibliya plateau (South Galala plateau). Awad and Abdellah (1966) dealt with the stratigraphy and the sedimentary history of the Upper Cretaceous rocks in the Southern and Northern Galala area. They found the Campanian rocks are the youngest Cretaceous sediments which are overlain by an Eocene limestone, indicating Late Cretaceous or post-Cretaceous movements. However, the second author found Maastrichtian sediments in South Galala later. Mazhar, Enany and Abdel Kader (1979) studied the Cretaceous-Lower Tertiary rocks cropping-out in the El Galala El Qibliya plateau. They found the Maastrichtian-Palaeocene rocks to be composed of chalky limestone and marls and overlain by the Esna Shale at the southern cliffs of El Galala El Qibliya.

Also they mentioned the Landenian-Lower Eocene rocks are represented at the southern cliffs of El Galala El Qibliya plateau by the Esna Shale.

Fig.14 - General view of Wadi Tarfa

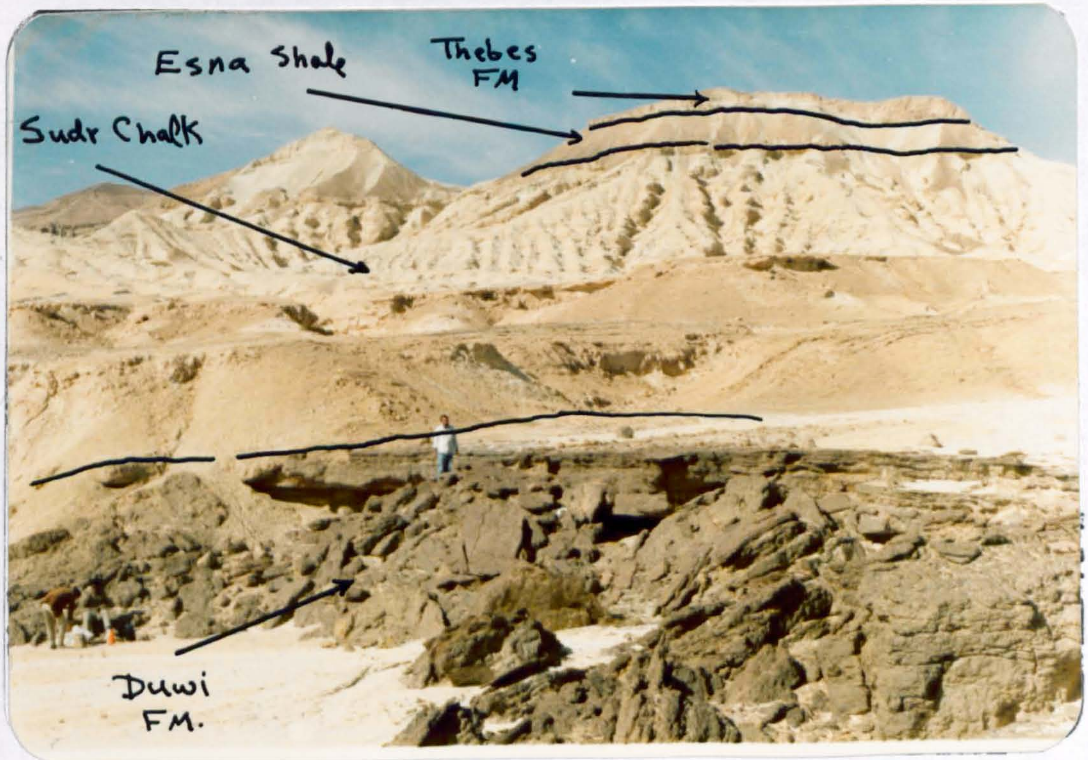


Fig.15 - The Upper Cretaceous-Lower Eocene sediments at Wadi Tarfa section

Fig.16 - Close up view of Sudr Chalk at Wadi Tarfa section

Fig.17 - Close up view of Esna Shale at Wadi Tarfa section

4-1 Wadi Tarfa section (Fig. 24)

The samples were collected from these rock units in stratigraphic order:

1. Sudr Chalk : (+ 88m)

   Limestone, brownish yellow, chalky, contains phosphatic grains, argillaceous at top with iron oxide patches, with gypsum veinlets, intercalated with thin shale beds.

2. Esna Shale : (+ 20m)

   Shale, pale grey to greenish grey, calcareous, gypsiferous, forming a gentle slope, at the middle there is a limestone bed, argillaceous, cherty, forming a cliff (4m).

CHAPTER III

BIOZONATION

The "stage" is considered to be the basic unit of chronostratigraphy which for the present study are all based upon European stratotypes. Chronological gaps and overlaps between various stages have been identified when the stratotype sections have been studied using several microfossil groups (e.g. calcareous nannofossils, planktonic foraminifera , dinoflagellates) as well as macrofossils. The nannofossil content of the late Cretaceous and the Tertiary of the stratotype sections has been studied by many authors, e.g. Maastrichtian (Bramlette and Martini 1964, p. 292; Sissingh 1977, p.56; Verbeek 1977, p.56, 58); Danian (Martini 1971, p. 751, 752; Perch-Nielsen 1979b, p. 117, 120; Romein 1979, p. 37, 46); Selandian (Perch-Nielsen 1979b, p.120); Thanetian (Bramlette and Sullivan 1961, p. 136; Martini 1971, p. 754; Hamilton and Hojjatzadeh 1982, p. 140 and Siesser *et al*. 1987). In Harland *et al*. (1982, p. 33, 34) the boundary between the Early and Late Maastrichtian is apparently located in the upper part of *Tranolithus phacelosus* Zone of Sissingh (1977), (the upper part of *T. phacelosus* Zone is equivalent to the lower part of *Arkhangelskiella cymbiformis* Zone used in this work). So, here the boundary between the Early and Late Maastrichtian is located in the lower part of *A. cymbiformis* Zone (Table 2) according to Harland *et al*. (1982).

Martini (1971) investigated the calcareous nannofossils from some localities at the type Danian. He mentioned (1971, p. 752) that the nannofossil content of the Danish localities indicate that the upper part of the type Danian belongs to his NP3 Zone (*Chiasmolithus danicus* Zone Martini 1970). Perch-Nielsen (1979b, p. 119) mentioned that she found only two specimens of *Ellipsolithus macellus* (its first

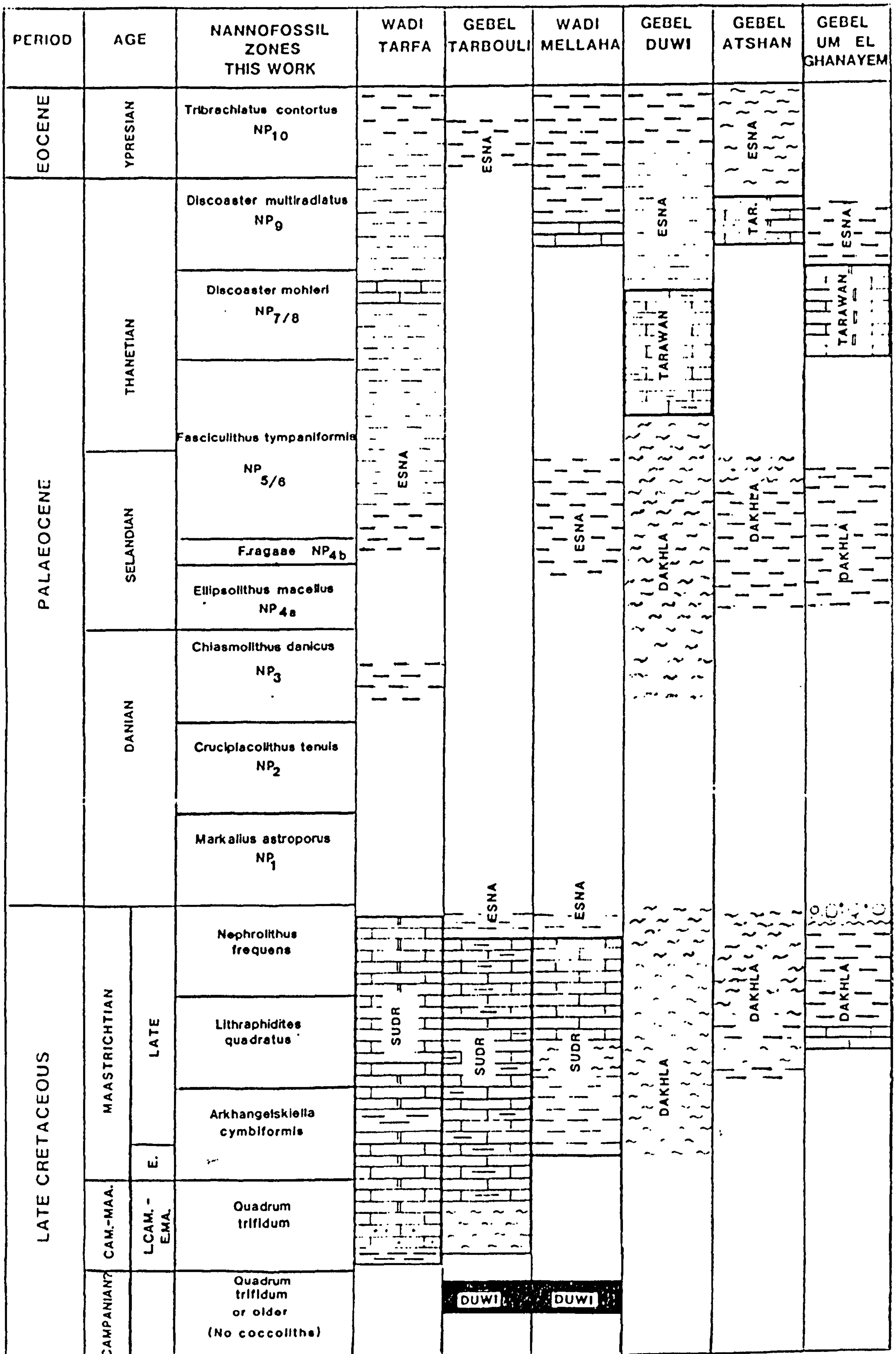


Fig.25- TIME AND ROCK STRATIGRAPHIC RELATIONS AT THE STUDIED SECTIONS

HARLAND et al. 1982		
AGE	Tethyan pelagic macrofossil zones (from Van Hinte 1978a)	Zones, Sissingh 1977
LATE MAASTRICHTIAN	Pachydiscus neubergicus	26
		25
		24
E.MA.	Acanthoscaphites tridens	23
L.C.	B.polyplocum	

SISSINGH 1977										
M. murus	N. frequens	L. quadratus	A. cymbiformis	R. levis	T. phacelosus	T. trifidus	Zones Sissingh 1977			AGE
							26		Nephrolithus frequens	LATE MAASTRICHTIAN
							c	25	A. cymbiformis	
							b			
						?	a			
						?	24		R. levis	EARLY MAASTRICHTIAN
						?	b	23	T. phacelosus	
							a			
										L. C.

THIS WORK					
Zones this work	Q. trifidum	A. cymbiformis	L. quadratus	N. frequens	AGE
N. frequens					LATE MAASTRICHTIAN
L. quadratus					
A. cymbiformis					
					E.
Q. trifidum					L.CA-E.M. / CAM.-MAA.

Table 2 – A comparison between Sissingh's zonation and the zonation used in this work for the Maastrichtian of Egypt. I put the boundary between the Early and Late Maastrichtian in the lower part of the Arkhangelskiella cymbiformis Zone (according to Harland et al. 1982)

EPOCH		AGE	ZONATION THIS WORK	ZONATION MARTINI 1971	
EO	E.	YPR	Tribrachiatus contortus	Marthasterites contortus	NP10
PALAEOCENE	LATE	THANETIAN	Discoaster multiradiatus NP 9	Discoaster multiradiatus	NP9
			Discoaster mohleri NP 7/8	Heliolithus riedelli	NP8
				Discoaster gemmus	NP7
		?—?	Fasciculithus tympaniformis NP6/5	Heliolithus kleinpellii	NP6
		SELANDIAN		Fasciculithus tympaniformis	NP5
			Fasciculithus ragaae NP 4b	Ellipsolithus macellus	NP4
			Ellipsolithus macellus NP 4a		
	EARLY	?—? DANIAN	Chiasmolithus danicus NP 3	Chiasmolithus danicus	NP3
				Cruciplacolithus tenuis	NP2
				Markalius inversus	NP1

Table 3 - A comparison between Martini's zonation and the zonation used in this work for the Early Tertiary of Egypt.

appearance marks the lower limit of NP4). Berggren *et al.* (1985, p. 154) draw the upper boundary of the Danian close to the upper limit of the *E. macellus* Zone NP4 (*E. macellus* Zone NP4 of Martini (1971) equal to *E. macellus* Zone (NP4a) and *Fasciculithus ragaae* Zone NP4b used in this work). They also suggested to consider the Selandian (of Denmark) to be the succeeding stage. This is because the Thanetian stage corresponds to Zone NP8 and part of NP9 Zone (Hamilton and Hojjatzadah 1982) which the Landenian (of Belgium) is equivalent to the Thanetian in its upper part and the lower part is slightly older than the basal Thanetian. The lower part of the Selandian is older than the lower part of the Landenian and the former represents a longer time interval.

Siesser *et al.* (1987) found the Zones NP6/7 (a combination of NP6 and NP7, due to the absence of the zonal marker of NP7, *Discoaster mohleri*, because of environmental or diagenetic reasons) and NP8 in the Thanet Formation at the stratotype localities in southeastern England. Also they noted the presence of NP9 Zone in Thanetian rocks out of the stratotype locality in England and elsewhere in Europe.

From the above discussion I considered the Palaeocene to consist of the Danian (its upper boundary is located at the boundary between NP3 and NP4a Zones), the Selandian (NP4 - NP5) and the Thanetian (NP6 - NP9) stages.

In the following zonal scheme used here the definitions of the zonal boundaries are based on the first occurrences of the species (because calcareous nannofossils are easily reworked which means that zonal boundaries based on the last occurrence of species is undesirable) except the upper limit of the *Quadrum trifidum* Zone where the last occurrence of the *Q. trifidum* is used to mark the upper boundary of the zone. This is because Q. trifidum is common in the Lower Maastrichtian sediments of the studied sections (Gebel Tarbouli and Wadi Tarfa sections), is easy to identify even in poorly preserved assemblages and provides the only way to subdivide this interval as no species evolve in this part.

The lower part of the A. cymbiformis Zone is distinguished by the last occurrences of Reinhardites levis, Tranolithus phacelosus, Broinsonia parca and Glaukolithus compactus. The upper part of the Arkhangelskiella cymbiformis Zone is distinguished by the first appearance of Lithraphidites praequadratus. The first occurrence of this species is used by Roth (1978) to mark the lower boundary of Lithraphidites praequadratus Zone Roth (1978). This zone is not used here because L. praequadratus is rare below L. quadratus Zone (in my sections) and common in the Lithraphidites quadratus Zone.

Useful Events:

In this work the last occurrence of Glaukolithus compactus is found to be a useful event because its highest occurrence is recorded in the lower part of the Arkhangelskiella cymbiformis Zone (in Gebel Tarbouli, Wadi Mallaha and Wadi Tarfa sections), the upper limit of the Ellipsolithus macellus Zone of Martini 1971 and the Fasciculithus tympaniformis Zone of Mohler and Hay (1967) are emended and a new Zone Fasciculithus ragaae is introduced.

1. Quadrum trifidum Zone Bukry and Bramlette 1970

Definition : The interval from the lowest to the highest occurrence of Quadrum trifidum.

Age : Late Campanian - Early Maastrichtian

Remarks:

Quadrum trifidum was used as a zonal marker by many authors particularly in tropical and low latitude areas (Thierstein 1976, and Perch-Nielsen 1977). The last occurrence of this species was used as a marker for the upper limit of this zone by Bukry and Bramlette (1970), Martini (1976), Verbeek (1977), Doeven (1983) and Stradner and Steinmetz (1984). A gap between the last occurrence of Q. trifidum and the entry of Lithraphidites quadratus was recorded by Martini (1976) and Doeven (1983). The latter author (1983, p.6, 9) reported a considerable gap (=Arkhangelskiella cymbiformis Zone Perch-Nielsen emend. Martini 1976) between the last occurrence of the former species and the first appearance of the latter one in the Maastrichtian rocks from offshore wells eastern Canada, Canadian Atlantic margin. Verbeek (1977, p. 25, 43) at El Kef section in western Tunisia did not report this gap due to the absence of samples from this interval. Sissingh (1977, p.52) recorded however, in the same section in Tunisia the highest occurrence of Q. trifidum below the lowest occurrence of Lithraphidites quadratus. In Egypt, the upper part of this zone was recorded by Faris (1984, p.108) at Gebel Duwi, Quseir area. During this work the upper part of this zone is found at Gebel Tarbouli and Wadi Tarfa sections. The absence of Eiffellithus eximius (some authors define the Campanian-Maastrichtian boundary by the extinction level of E. eximius) in the upper part of this zone at the above mentioned sections may suggest the Early Maastrichtian age of this part, although Doeven (1983, p.3) found the highest occurrence of this species just below the entry of Lithraphidites quadratus in Maastrichtian sediments, which is probably reworked. In this work the highest occurrence of Rucinolithus hayi , Quadrum gartneri is found at the upper part of the zone. The highest occurrence of Quadrum trifidum (the zonal marker) and Q. sissinghii is recorded at the top (the upper boundary) of the zone in Gebel Tarbouli and Wadi Tarfa sections. GlauKolithus compactus and Reinhardtites levis are generally common while Broinsonia parca and Tranolithus phacelosus are rare throughout the upper part of the zone. The lower boundary of this Zone is not observed in this study.

2. Arkhangelskiella cymbiformis Zone Perch-Nielsen 1972, emend. Martini 1976.

Definition : This zone ranged from the last occurrence of Quadrum trifidum to the first occurrence of Lithraphidites quadratus

Age : Early-Late Maastrichtian

Remarks:

Martini (1976) reported a gap between the highest occurrence of Quadrum trifidum and the entry of Lithraphidites quadratus at the low latitude sites of D.S.D.P. Leg 33 in the central Pacific latitude 15-30°N which he defined as the Arkhangelskiella cymbiformis Zone. Arkhangelskiella cymbiformis Zone was recorded by Hattner and Wise (1980, p.45, 48, 52) in the Upper Cretaceous sediments from South Carolina. Also the zone was found by Doeven (1983, p.6, 9) in the Maastrichtian from offshore wells on the Canadian Atlantic margin. From, Egypt, Abdelmalik et al. (1978, p.221) recorded the zone at Bir El-Marka, West Central Sinai.

In my sections this zone is found at Wadi Tarfa, Gebel Tarbouli, and Wadi Mellaha (the lower most part of the zone is missing) sections. The last occurrence of Broinsonia parca is just above the lower boundary of the zone at Gebel Tarbouli and Wadi Tarfa sections. The absence of this species in the A. cymbiformis Zone at Wadi Mellaha section is due to the absence of the lower part of the zone. Tranolithus phacelosus is rare in the lower part of the zone. The last occurrence of this species is found at the same last occurrence level of Reinhardtites levis at Gebel Tarbouli section and below the last occurrence level of Reinhardtites levis and Glaukolithus compactus in the zone at Wadi Tarfa and Wadi Mellaha sections. The highest occurrence of Glaukolithus compactus is below the last occurrence of R. levis in the zone at Gebel Tarbouli, Wadi Tarfa and Wadi Mellaha sections. Reinhardtites levis and Glaukolithus compactus are common, even in poorly preserved assemblages, throughout the Quadrum trifidum Zone and gradually become rare towards their highest occurrences in the lower part of the Arkhangelskiella cymbiformis Zone.

3. Lithraphidites quadratus Zone Čepek and Hay 1969

Definition: Interval zone from the first occurrence of Lithraphidites quadratus to the first occurrence of Nephrolithus frequens

Age : Late Maastrichtian

Remarks:

This zone was first established by Čepek and Hay (1969a,p.329) from its type locality along the Alabama River between 151.9 (z-229) and mile 143.2 (Prairie Bluff Landing, z-231 in Figure 3). Verbeek (1976, p.141) mentioned the presence of the zone (the top is marked by the first appearance of M. murus) from El Kef sections, Tunisia. This zone was the uppermost zone found by Hattner and Wise (1980, p.43, 48, 52) in the Upper Cretaceous sediments from South Carolina. Also it was detected by Doeven (1983, p.6, 10) from offshore wells at the Canadian margin. From Egypt, the upper part of this zone was recorded by Perch-Nielsen et al. (1978, p.342) at Gebel Oweina, Nile Valley, and by Faris (1984, p.108) at Gebel Duwi, Quseir and at Ain Amur and Ghanima sections in the Kharga Oasis. During this work, the Lithraphidites quadratus Zone is found at all the studied sites.

4. Nephrolithus frequens Zone Čepek and Hay (1969), emend. Romein 1979

Definition: This zone spans the interval from the first occurrence of N. frequens to the extinction level of most of Cretaceous species.

Age : Late Maastrichtian

Remarks:

This zone was first established by Čepek and Hay (1969a,p.332) from its type locality at Road cut on Lowndes County Road 7 from Braggs, Lowndes County, Alabama to Greenville, Butler County, Alabama, 4.45 miles south of the intersection with Alabama Highway 21; top of Prairie Bluff Chalk. Čepek and Hay used the extinction level of most Cretaceous calcareous nannofossils to define the upper boundary of this zone. Romein (1979, p.50) has emended the definition of the upper boundary of this zone to be marked by the mass occurrence (or increased frequency) of Braarudosphaera bigelowi and/or Thoracosphaera operculata. This seems to be acceptable, since Nephrolithus frequens and many other Cretaceous species were found reworked into the overlying Palaeocene sediments in many sections in the world.

Perch-Nielsen (1977, p.702) on the D.S.D.P. Leg 39, Southern Atlantic Ocean, emended the upper boundary of this zone to the first occurrence of M. murus. This is not followed here, although the species is present in the upper Maastrichtian of the investigated areas. During the SEM investigation (of Late Maastrichtian samples from Wadi Tarfa and Gebel Tarbouli sections) of M. murus it was observed that this species is very rare and highly affected by dissolution and overgrowth (which is probably the reason for its rare occurrence) which make it very difficult to recognise. Nephrolithus frequens is known to be more common in boreal areas while M. murus is a tropical and subtropical species (Worsley and Martini 1970). Perch-Nielsen (1985, p.348) mentioned that this zone works well in high latitudes, where N. frequens is relatively common. This species was used by Doeven (1983, p.6, 10) for the Latest Maastrichtian zone from offshore wells at the Canadian Atlantic margin. In low latitude areas this zone was used by Verbeek (1976, II, p.133). He used the first occurrence of N. frequens to mark the lower boundary of the N. frequens Zone Cepek and Hay 1969 at the El Kef section, Tunisia. Also in Egypt, the lower part of this zone was recorded by Perch-Nielsen et al. (1978, p.340) at Gebel Oweina, Nile Valley and latter by Faris (1984, p.386) from the western Desert (Dakhla and Kharga Oasis) and Quseir area. During this work, the lower part of the zone was recorded at Gebel Duwi, Gebel Atshan, Gebel Tarbouli, Wadi Mellaha and Wadi Tarfa sections. The absence of N. frequens Zone at Gebel Um El Ghanayem section is due to erosion as the top of the Maastrichtian is marked by the unconformity surface (Conglomerate band) or due to the restricted environment which happened at that time during the major uplifting at the end of the Maastrichtian and caused the presence of few species (low divesity). The first appearance of Micula murus and M. prinsii is detected within the zone.

Markalius astroporus Zone (NP1) Hay and Mohler in Hay et al. (1967) and Cruciplacolithus tenuis Zone (NP2) Hay and Mohler in Hay et al. 1967

Remarks:

These are the oldest (Early Danian) nannofossil zones known to occur in the Palaeocene. They are not found in the sections studied here. Markalius astroporus Zone was, however, reported to be present possibly in the Gebel Abu Had section at the mouth of Wadi Quena (Kerdany 1970, p.36). The C. tenuis Zone (NP2) has not been found in Egypt, where this zone was mentioned to occur by some authors (e.g. Kerdany, 1970) it was meant in the sense of Hay and Mohler (1967), where it included the later described Zones NP2, NP3 and NP4 (=NP4a and NP4b, this work). The erosion and the lack of circulation in the basin is responsible for the absence of these zones at Gebel Um El Ghanayem. The absence of the top of the N. frequens Zone, NP1, NP2, and the lower part of NP3 Zone at Gebel Duwi (Fig. 20) is most likely due to regression at the end of the Cretaceous which cause the formation of an isolated basin with lack of supply of oxygen and the deposition of black non-calcareous shale. The above mentioned zones are found to be absent plus from NP5/6 Zone to the base of NP10 Zone at Gebel Tarbouli. Also at Wadi Mellaha (Fig. 23) from the top of the Nephrolithus frequens Zone to the lower part of (NP4a) are missing, probably due to them being missed during sampling as no interruption in the rock sequence was observed in the field. Faris (1984, p.385) studied the Cretaceous-Tertiary boundary from different areas in central Egypt and found the uppermost Maastrichtian and the Lower Danian (from the upper part of N. frequens Zone to the base of the Chiasmolithus danicus Zone) to be missing at Mut section, Dakhla Oasis, and Duwi section, Quseir area.]

5. Chiasmolithus danicus Zone (NP3) Martini 1971

Definition: From the first occurrence of Chiasmolithus danicus to the first occurrence of Ellipsolithus macellus

Age : Danian

Remarks:

This zone probably corresponds to the middle part of the Cruciplacolithus tenuis Zone which was introduced by Mohler and Hay (1967, p.434) at Pont Labau S.W.France. Martini (1971) lowered the upper boundary of the C. tenuis Zone and inserted two zones (NP3, NP4) in between the emended C. tenuis NP2 and Fasciculithus tympariformis Zone Mohler and Hay (1967). Romein (1979, p.53) did not find C. danicus (the zonal marker of NP3) in the Caravaca section in S.E. Spain and in the Nahal Avdat section in Israel, thus he draw the upper boundary of C. tenuis at the first occurrence of the E. macellus Zone (NP4) Martini (1971).

In Egypt Faris (1984, p.386) found the upper part of C. danicus Zone (NP3) at Mut section, Dakhla Oasis, Taramsa section, Qena and at the Gebel Duwi, Quseir. During this work the upper part of this zone is found at Gebel Duwi, Gebel Atshan and Wadi Tarfa sections. The first appearance of Neochiastozygus modestus, D. imbriei and N. concinnus is detected in the upper part of the zone. Thoracosphaera saxea, T. operculata, Ericsonia cava and E. subpertusa are abundant in this zone.

6. Ellipsolithus macellus Zone (NP4a) Martini (1971). emend. this work.

Definition : This zone spans the interval from the first occurrence of Ellipsolithus macellus to the first occurrence of Fasciculithus ragaae.

Age : "early" Selandian

Remarks:

The upper limit of Martini's Ellipsolithus macellus Zone (NP4) is marked by the first appearance of Fasciculithus tympaniformis. In the present work the definition of the upper boundary is changed to be marked by the first occurrence of Fasciculithus ragaae n. sp.. The first occurrence of F. ragaae is below the first occurrence of

Fasciculithus tympaniformis in Gebel Atshan, Gebel Duwi, Gebel Um El Ghanayem, Wadi Mellaha and Wadi Tarfa sections. The first occurrence of Chiasmolithus consuetus and Fasciculithus ulii, the last occurrence of Diadochiastozygus imbriei and the whole vertical range of Diadochiastozygus eosaepes and D. saepes is recorded in the zone.

7. Fasciculithus ragaae Zone (NP4b) Abdel Baky, this work

Definition : This zone spans the interval from the first occurrrence of Fasciculithus ragaae to the first occurrence of Fasciculithus tympaniformis

Age : "middle" Selandian

Remarks:

This zone is equivalent to the upper part of Martini's Ellipsolithus macellus Zone (NP4) Martini (1971). Fasciculithus ragaae has a short vertical range (from the base of the F. ragaae Zone to the lower part of the Fasciculithus tympaniformis Zone Mohler and Hay 1967, emend. this work). This species differs from the similar form Fasciculithus ulii by its broader median cycle (the median cycle of F. ragaae has a larger diameter than the column while the median cycle of F. ulii has a smaller diameter than the column) and more elongated cone. This zone is found at Gebel Duwi, Gebel Atshan, Wadi Tarfa, Wadi Mellaha and Gebel Um El Ghanayem sections. The last occurrence of Chiasmolithus danicus and the first occurrence of Fasciculithus janii is recorded in the zone.

8. Fasciculithus tympaniformis Zone (NP5/6) Mohler and Hay (1967), emend. this work.

Definition : This zone spans the interval from the first occurrence of Fasciculithus tympaniformis to the first occurrence of Discoaster mohleri

Age : Selandian - Thanetian

Remarks:

This zone was introduced by Mohler and Hay (1967) as the interval from the first occurrence of Fasciculithus tympaniformis to the first occurrence of Heliolithus kleinpellii (=Bomolithus kleinpellii, this work). Here, the upper limit of this zone is extended to be marked by the first occurrence of Discoaster mohleri. This means that the F. tympaniformis Zone (NP5/6) which is used in this work is a combination of the F. tympaniformis Zone Mohler and Hay (1967) and the Heliolithus kleinpellii (=Bomolithus kleinpellii, this work) Zone Mohler and Hay (1967). This is because Heliolithus kleinpellii is rare and discontinuously present particularly below the Discoaster mohleri Zone in the studied sections. In the lower part of this zone the first occurrence of Fasciculithus gelelii, Cruciplacolithus frequens, Bomolithus elegans, B. cantabriae and the last occurrence of Fasciculithus ragaae, F. ulii is recorded. In the upper part of the zone the first occurrence of Heliolithus kleinpellii, B. megastypus, Discoaster drieveri, Fasciculithus bobii and the last occurrence of Fasciculithus janii is recorded. The whole vertical range of Fasciculithus billii, Discoaster atefii, D. duwiensis is detected within the zone.

9. Discoaster mohleri Zone (NP7/8) Hay (1964), emend. Romein 1979

Definition : Interval zone from the first occurrence of Discoaster mohleri to the first occurrence of D. multiradiatus

Age : "early" Thanetian

Remarks:

Bukry and Percival (1971, p.129) mentioned that D. mohleri is a cosmopolitan species present in deep-ocean cores from the Atlantic and the Pacific Ocean (Type locality D.S.D.P. Core 47.2-9-6, 0-5cm, Shatsky Rise, Pacific Ocean) and from land outcrops in France and Trinidad.

Discoaster gemmeus Zone Hay (1964) is changed to the D. mohleri Zone as Bukry and Percival (1971, p.128) found that D. gemmeus was described by Stradner (1959) from younger sediments of Middle Eocene age and is not found in the Palaeocene while D. mohleri is a Palaeocene form. Romein (1979, p.54) inserted the H. riedelii Zone (NP8) at the top of the D. mohleri Zone (NP7/8) and emended the upper limit of the zone to be restricted to the first occurrence of D. multiradiatus. This is followed here as H. riedelii is found very rare at Gebel Duwi and Gebel Atshan sections only in the lower part of the D. multiradiatus Zone. The absence of this species below the D. multiradiatus Zone at the above mentioned sections and at the other sections due to its short stratigraphic range which can easily be missed during sampling. Varol (1983, p.443) recorded the H. riedelii Zone (equal the lower part of D. mohleri Zone) from Kokaksu section from northern Turkey. During this work the D. mohleri Zone is found at Gebel Duwi, Gebel Atshan, Gebel Um El Ghanayem and Wadi Tarfa sections. The first appearance of Fasciculithus involutus, Heliolithus riedelii and Discoaster mediosus was recorded at the upper part of the zone.

10. Discoaster multiradiatus Zone (NP9) Bramlette and Sullivan 1961

Definition : Interval zone from the first occurrence of Discoaster multiradiatus to the first occurrence of Tribrachiatus nunnii (Bronnimann and Stradner) Romein.

Age : "late" Thanetian

Remarks:

This zone was first established by Bramlette and Sullivan (1961) from its type locality at Lodo Gulch and side gully, lower part of Lodo Formation (Unit 2), Fresno County, California. Roth (1973) recorded this zone on the D.S.D.P. in the Central Pacific. Gartner (1971) recorded the zone from the east coast of Florida. Romein (1979) found the zone in Israel and Spain. In Egypt, it was recorded by many authors from different areas of Egypt, Abdelmalik et al. (1978) at Bir El Markha, West Central Sinai, Perch-Nielsen, et al. (1978) at Gebel

Gurnah (Loxor) and at Gebel Oweina, Nile Valley and by Faris (1984) from Kharga Oasis, Qena and Quseir area. In this project D. multiradiatus is found at all the studied sections except Gebel Tarbouli section, where the Maastrichtian is overlain by the T. contortus Zone (NP10). The first appearance of Campylosphaera delas, Chiasmolithus californicus, Discoaster amrii, D. nobilis, D. lenticularis, D. salisburgensis, Neochiastozygus junctus is recorded from the lower part of the zone. Neochiastozygus concinnus, N. perfectus, Cruciplacolithus tenuis, C. frequens, become extinct within the zone. Discoaster ornatus, D. diastypus, D. mahmoudii, D. okadai, Rhomboaster bitrifida, R. calcitrapa appeared at the top of the D. multiradiatus Zone. Also the members of Heliolithus and Bomolithus groups become extinct in the lower part.

11. Tribrachiatus contortus Zone (NP10) Hay 1964

Definition : Interval zone from the first occurrence of Tribrachiatus nunnii to the last occurrence of Tribrachiatus contortus.

Age : "early" Ypresian

Remarks:

The Palaeocene-Eocene boundary is generally placed at the base of this zone (Martini 1971). Bukry (1973a, p.689) established the D. diastypus Zone (=T. contortus Zone and Discoaster binodosus Zone) in D.S.D.P. material in the Caribbean Sea for low latitude deep-ocean sediments. He placed the Palaeocene-Eocene boundary at the first appearance of Discoaster diastypus. Here D. diastypus's first appearance was found in D. multiradiatus NP9 (at Gebel Duwi section). In Egypt, Kardany (1970) used a slightly different definition of the Marthastrites contortus (=Tribrachiatus contortus) Zone than the one used by Martini (1971), in that he considered the upper boundary to be at the first occurrence of M. tribrachiatus. Tribrachiatus contortus Zone (NP10) was found in Egypt by Perch-Nielsen et al. (1978) at Gebel Gurnah (Loxor), Abdelmalik et al. (1978) at Bir El-Markha (west central Sinai) and by Faris (1984) at Gebel Duwi (Quseir area) and at Taramsa (Qena).

During this work the lower part of the zone is found at Gebel Duwi, Gebel Atshan, Gebel Tarbouli, Wadi, Mellaha and Wadi Tarfa section. The first appearance of *Discoaster binodosus* is recorded at the base of the zone while the last occurrence of *Rhomboaster bitrifida*, *Tribrachiatus nunnii*, and *Discoaster mediosus* is found in the lower part. The extinction of the last members of the *Fasciculithus* group (*F. tympaniformis* and *F. involutus*) also occurred in the lower part of the zone. The upper boundary of this Zone is not observed in this study.

CHAPTER IV

EVOLUTIONARY LINEAGES

Evolutionary lineages for genus MICULA (Figs. 26, 27)

Micula murus and *M. prinsii* are the youngest members of this group. *Micula murus* is the marker species of the latest Maastrichtian in low-latitude areas. Each of the two species is formed of two closely appressed cycles of elements. Each cycle is formed of four elongate elements. In the Wadi Mellaha section, *M. prinsii*'s first appearance is in the latest Maastrichtian while *M. murus*'s first appearance is in older samples in the Late Maastrichtian at the same section. At the Wadi Tarfa section they first appeared in the same level (sample 52). In the same sample another species with transitional characters between *M. murus* and *M. staurophora* is detected (*Micula* sp.).

Micula murus differs from *Micula* sp. by its more elongated elements of the outer cycle and more reduced elements of the inner cycle of the convex side (Fig. 26, pl.5, fig.15; pl.6, fig.1). *Micula murus* might be evolved from *Micula* sp. in the Maastrichtian. Also sometime in the latest Maastrichtian *M. prinsii* evolved from *M. murus* by the reduction of the inner cycle of the convex side, the four elements of the same cycle became more elongated and narrower and the four elements of the outer cycle are forming longer arms with bifurcate ends (Fig. 26).

The lineage suggested here is not clear in my material because no transitional forms is found, except *Micula* sp. which is very rare and found at the same stratigraphic level with *M. murus* and *M. prinsii* in the *Nephrolithus frequens* Zone at Wadi Tarfa section.

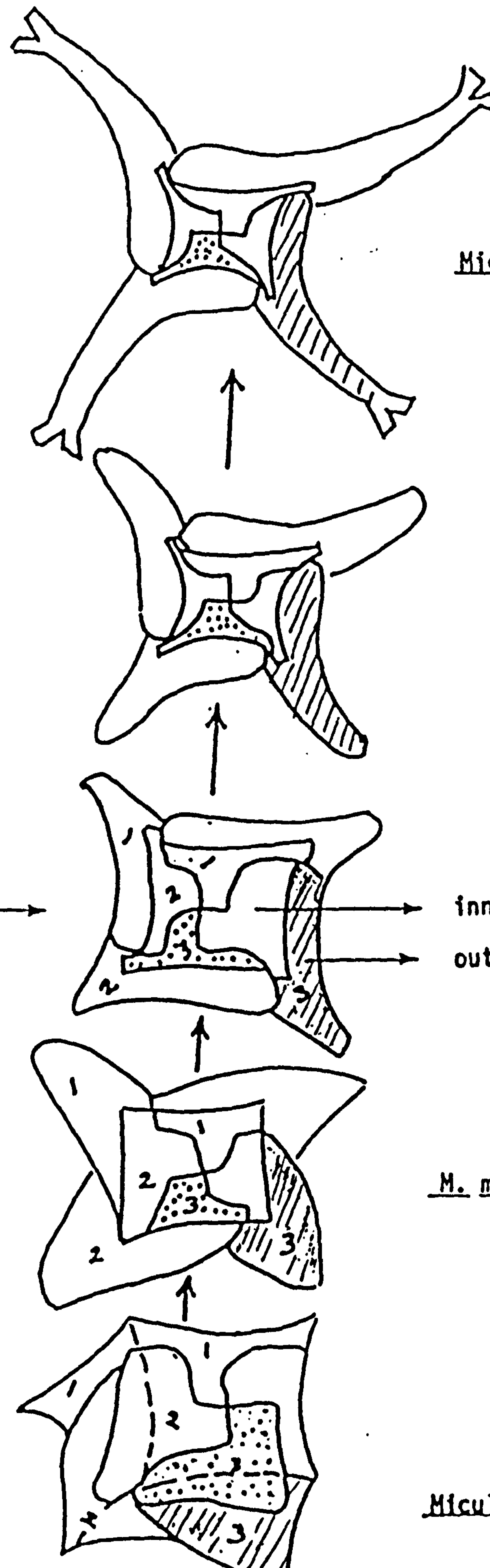


Fig.26-The transition from Micula murus to M. prinsii

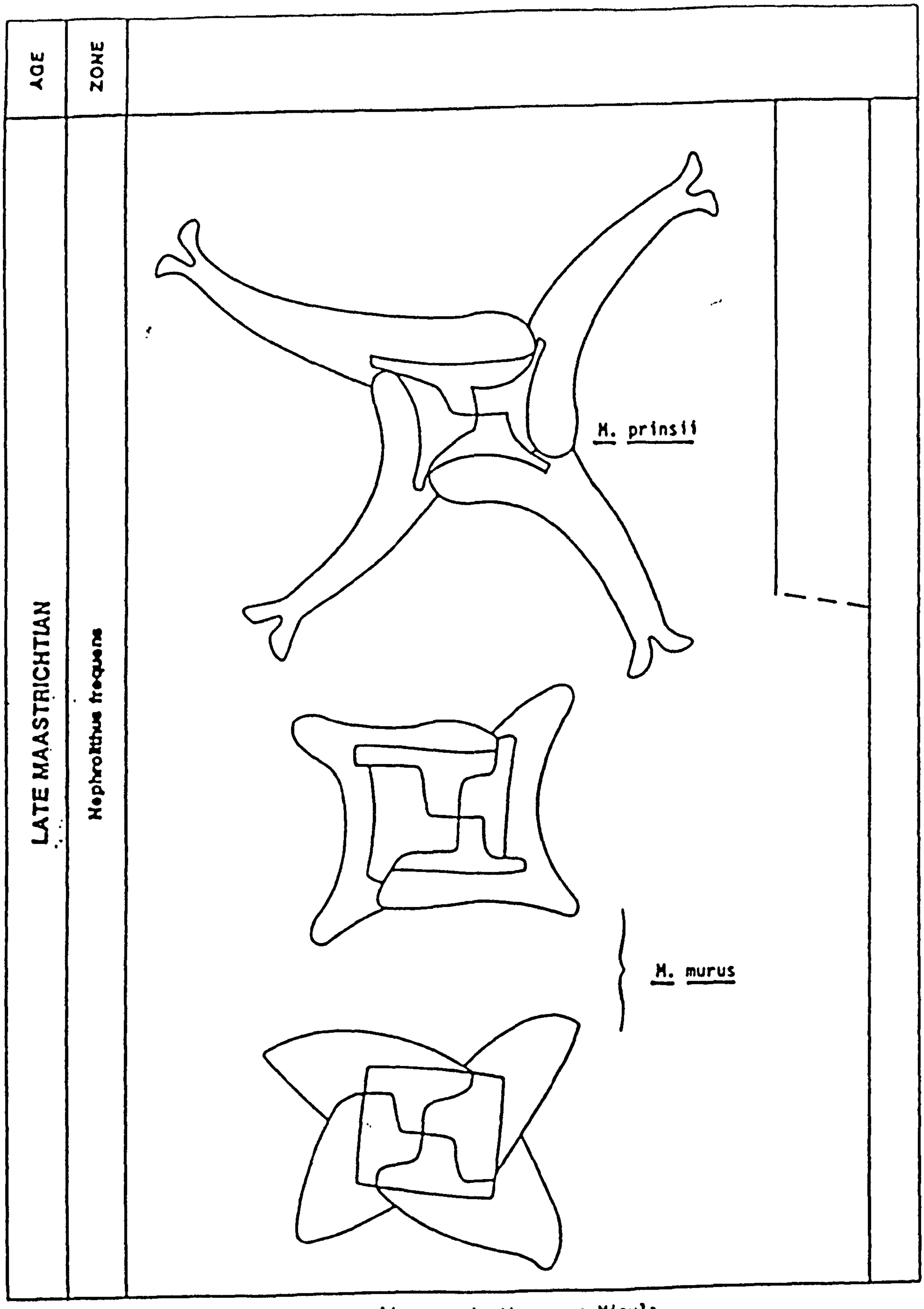


Fig.27- Evolutionary lineages in the genus *Micula*
(based upon Perch-Nielsen 1979a, fig. 14)

Evolutionary lineages of genus LITHRAPHIDITES (Fig. 28)

Roth (1978, p.740) has suggested an evolutionary lineage for the Lithraphidites species of the Maastrichtian. The species which have been included are L. carniolensis, L. praequadratus and L. quadratus. He based his lineages on the length to width ratio (L/W). So, L. carniolensis with a length to width ratio (L/W) of 5.0 or more. Lithraphidites praequadratus is evolved from L. carniolensis by the increase of the width and the L/W ratio is between 4.9 and 3.6. Lithraphidites quadratus is the youngest form which evolved from L. praequadratus by the increase of the width and the (L/W) ratio is 3.5 or less. In the Maastrichtian samples of this project all the above mentioned species (plus L. grossopectinatus) are found. Seyve (1984, p.408) mentioned that the validity of L. grossopectinatus is doubtful because the characteristic tooth-like margin may be the result of the differential dissolution on the outer margin of L. quadratus (this is discussed in Chapter 6, page 195). Perch-Nielsen (1986, p.836) described a new species L. kennethii she mentioned that L. kennethii is distinguished from L. quadratus by its two spikes at the extremities of the short broad blades. This form is considered an etched form of L. quadratus. Calculations of the L/W ratio for Lithraphidites group is carried out from Gebel Tarbouli section (Fig. 29).

Thirty specimens are measured in each sample. Only well preserved specimens which are lying flat are used. The length to width ratio (L/W) decreases in progressively younger assemblages from the Quadrum trifidum Zone to the N. frequens Zone. In samples 10 and 20 the length to width ratio of the specimens is 5.0 or more. These specimens are considered L. carniolensis. In sample 22 some specimens have a length to width ratio of greater than 3.7 and less than 5.0. These specimens are considered to belong to L. praequadratus. In sample 24 only two specimens with a length to width ratio of less than 3.8 are found and assigned to L. quadratus. The number of specimens of L. quadratus and L. praequadratus increases in progressively higher assemblages in the Late Maastrichtian of Gebel Tarbouli section.

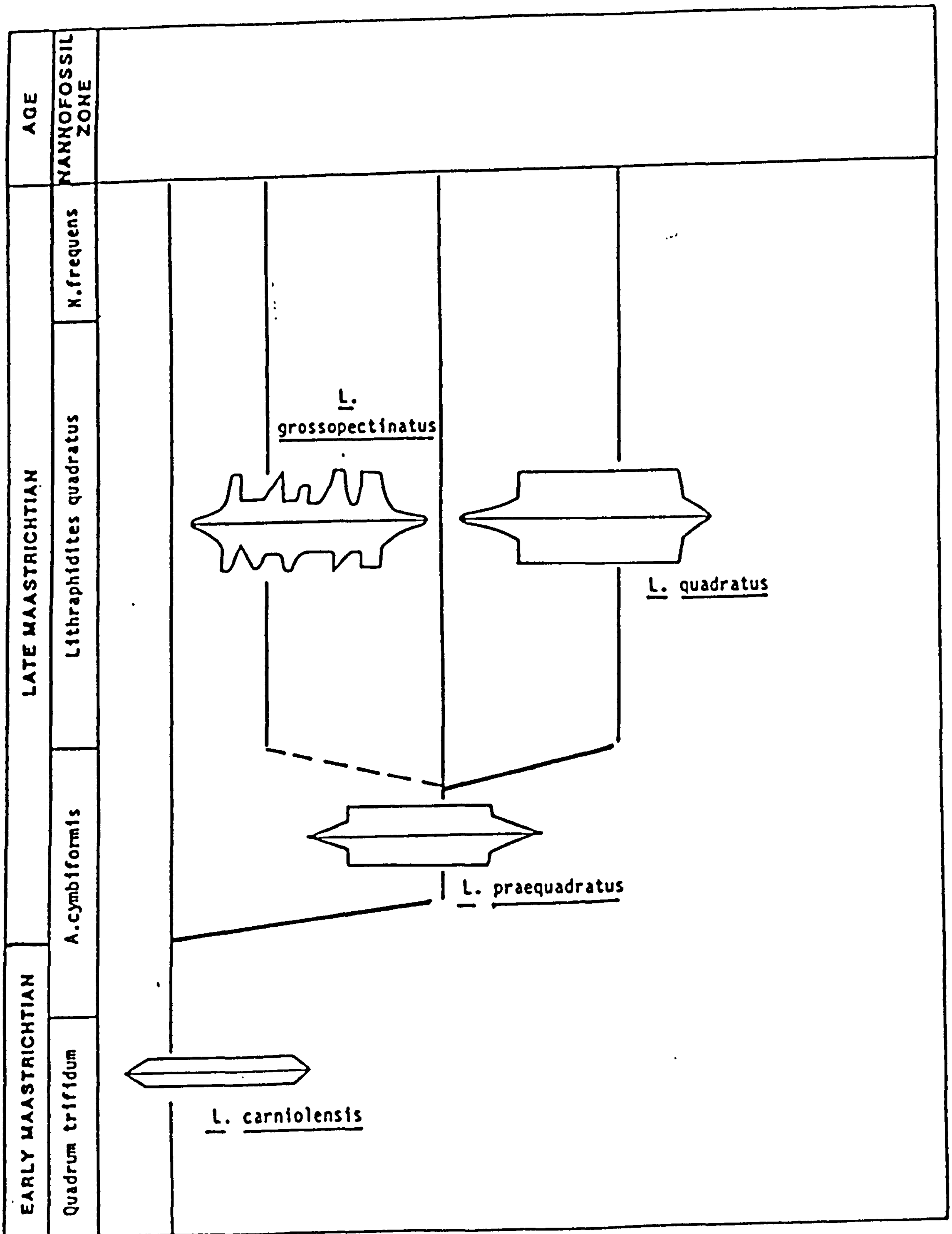


Fig.28 – Evolutionary lineages in the genus Lithraphidites (after Roth 1978, fig.4 and Perch-Nielsen 1979, fig.15)

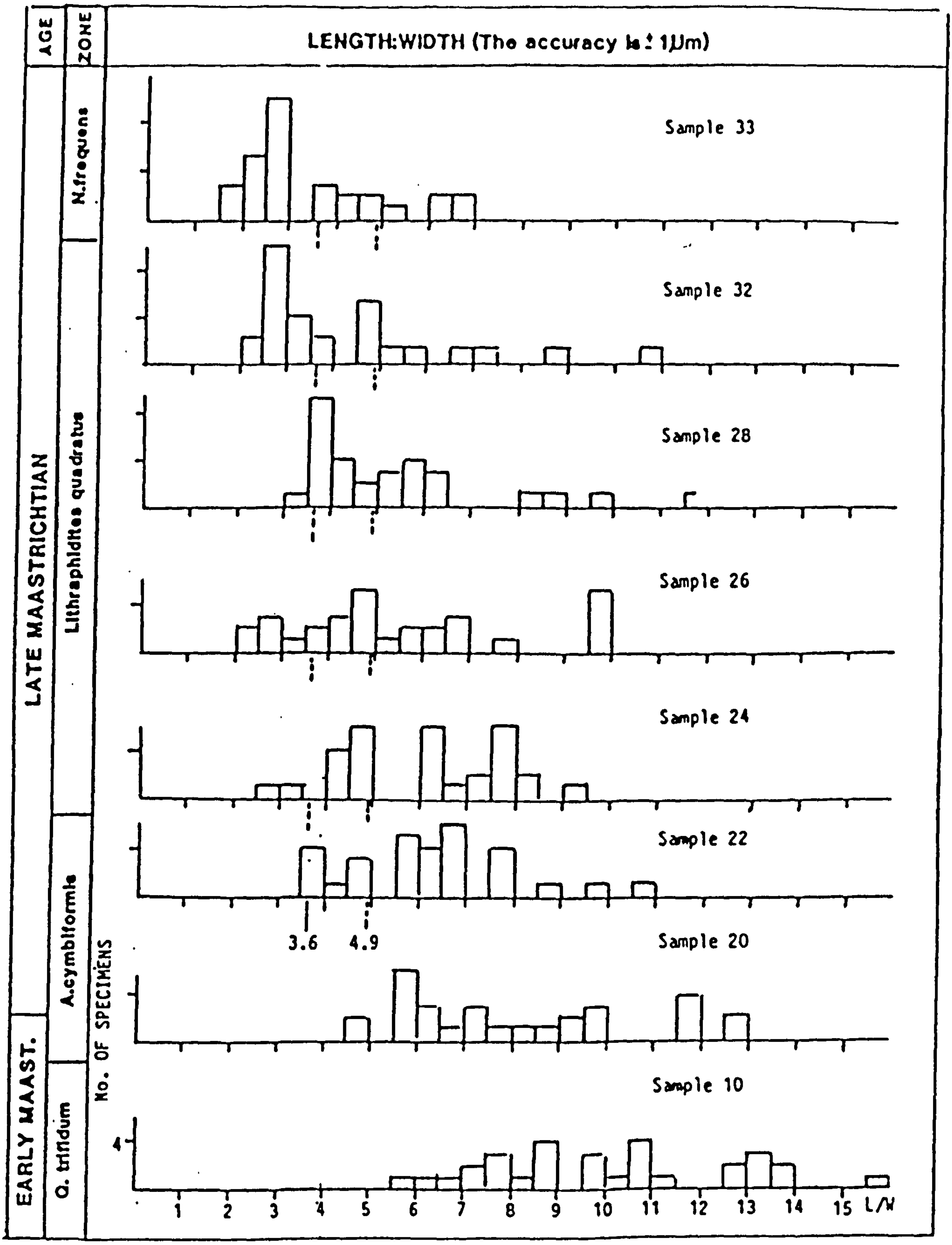


Fig.29- Histograms showing the change of the length (L.) to width (W) Ratio in Lithraphidites measured in the Maastrichtian of Gebel Tarbouli section.

Lineages in the genus CRUCIPLACOLITHUS (Fig. 30)

Romein (1979, p. 59) has suggested an evolutionary lineage for the genus *Cruciplacolithus*. Perch-Nielsen 1985 (in "Cenozoic" calcareous nannofossils, p. 460) has discussed the evolutionary lineages in the genera *Campylosphaera*, *Chiasmolithus* and *Cruciplacolithus*.

In the Palaeocene and Early Eocene of Egypt only four species of genus *Cruciplacolithus* are found. These species, are *Cruciplacolithus primus*, *C. edwardsii*, *C. tenuis*, and *C. frequens*. *Cruciplacolithus primus* and *C. edwardsii* are rare species in the Early Palaeocene. *Cruciplacolithus tenuis* and *C. frequens* are generally common through the Palaeocene. *Campylosphaera dela* is the only representative of genus *Campylosphaera*.

The earliest nannofossil zone in the Lower Tertiary in Egypt is *Chiasmolithus danicus* Zone (NP3). As the lower part of the Lower Palaeocene (*Markalius astroporus* Zone NP1, and the *Cruciplacolithus tenuis* Zone NP2) is missing, the evolutionary relations for the early representatives of this group are not seen. These species are *Cruciplacolithus edwardsii*, *C. primus* and *C. tenuis*. Romein (1979, p.61,62) has suggested that both *Cruciplacolithus edwardsii* and *C. tenuis* are evolved from *C. primus* by an increase in the size of the two forms and a change the orientation of the crossbars to make a slight angle with the main axes in the former species. Also, the presence of foot-like extensions on one side of the termination of each crossbar in *C. tenuis* is characteristic and links it to *C. frequens*, in which the extensions are more pronounced and the crossbars are slightly deviated from the major axes.

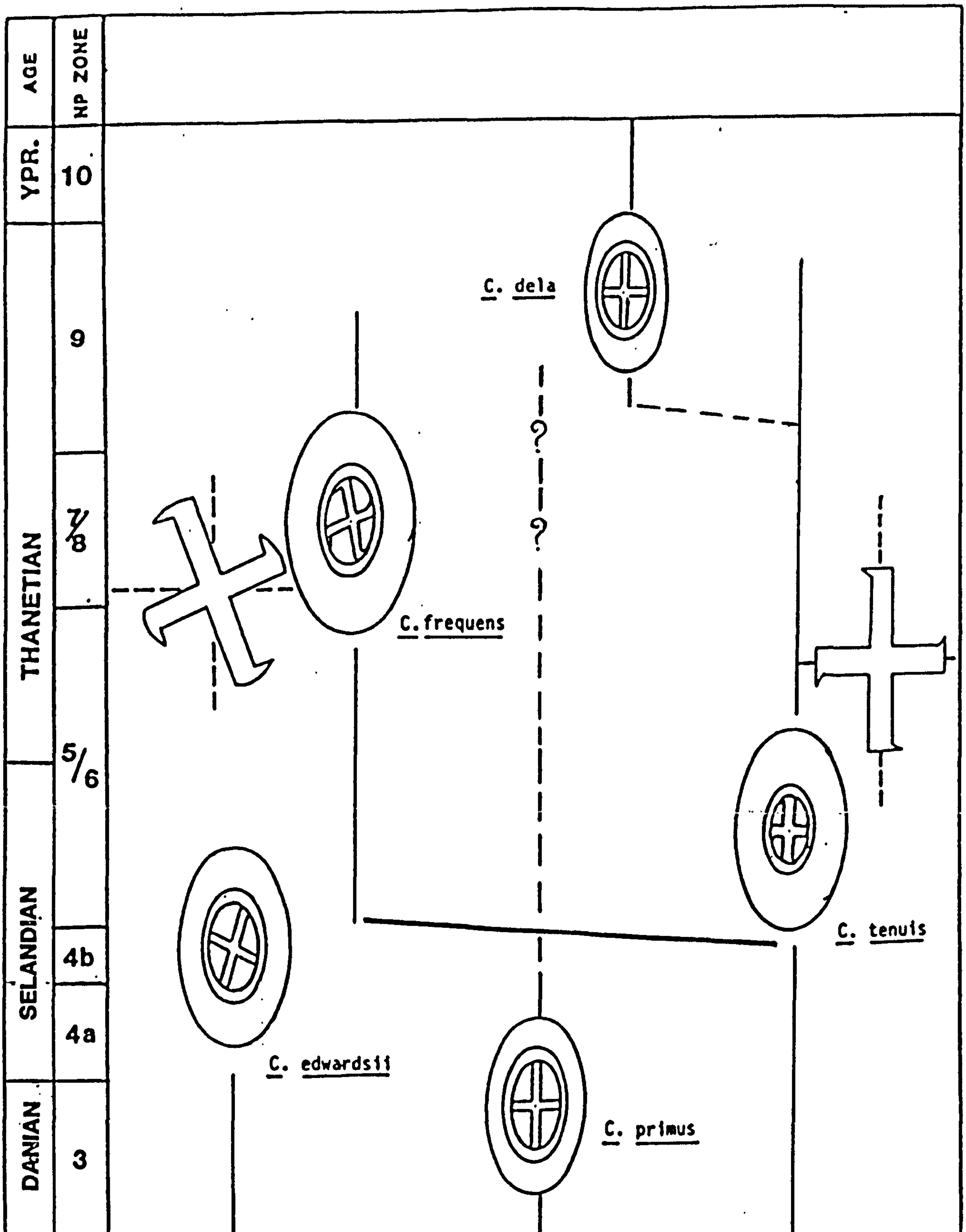


Fig.30-Evolutionary lineages in the genera *Cruciplacolithus* and *Campylosphaera* (based partly upon Romein 1979, fig. 29)

In this study Cruciplacolithus frequens is observed to be evolved from C. tenuis (in the lower part of the F. tympaniformis Zone NP5/6, not in the D. mohleri Zone NP7/8 as mentioned by Romein 1979, fig. 29). This is because in the Um El Ghanayem section, Kharga Oasis, Western Desert specimens with cross bars slightly deviated from the major axis by about 5 degrees, are detected in sample 34 (Fasciculithus tympaniformis Zone NP5/6) also the feet at the ends of the bars are more developed than in C. tenuis and it became more elongate in younger assemblages. Both of these species disappeared in the Upper Palaeocene (NP9). Campylosphaera dela probably evolved from Cruciplacolithus tenuis in the base of the D. multiradiatus Zone (NP9) by reduction in the dimensions, disappearance of the feet at the ends of the central bars and greater curving of the margin.

Lineages in the genus ERICSONIA (Fig. 31)

Lineages in this genus have been described by Romein (1979, p. 66). Most of his lineages are conformed to in this project. Ericsonia sp. A is included and an earlier appearance of Ericsonia robusta is detected. In the Palaeocene and Early Eocene of Egypt five species are found. These species, from older to younger, are Ericsonia cava, E. subpertusa, E. eopelagica, E. robusta and Ericsonia sp. A. These species are common to abundant except for E. sp. A and E. robusta which are rare. E. cava and E. subpertusa are the early representatives of this group in the study material. The origin of both species is not seen due to the absence of the early part of the Lower Paleocene. Ericsonia eopelagica is evolved from E. cava in the E. macellus Zone (NP4a). In Gebel Duwi section, at the base of NP4a Zone forms with a larger, gently outward sloping distal shield and less steep wall inwards on the distal side start to appear. Intermediate forms between the two species are observed in samples 36, 37, 38.

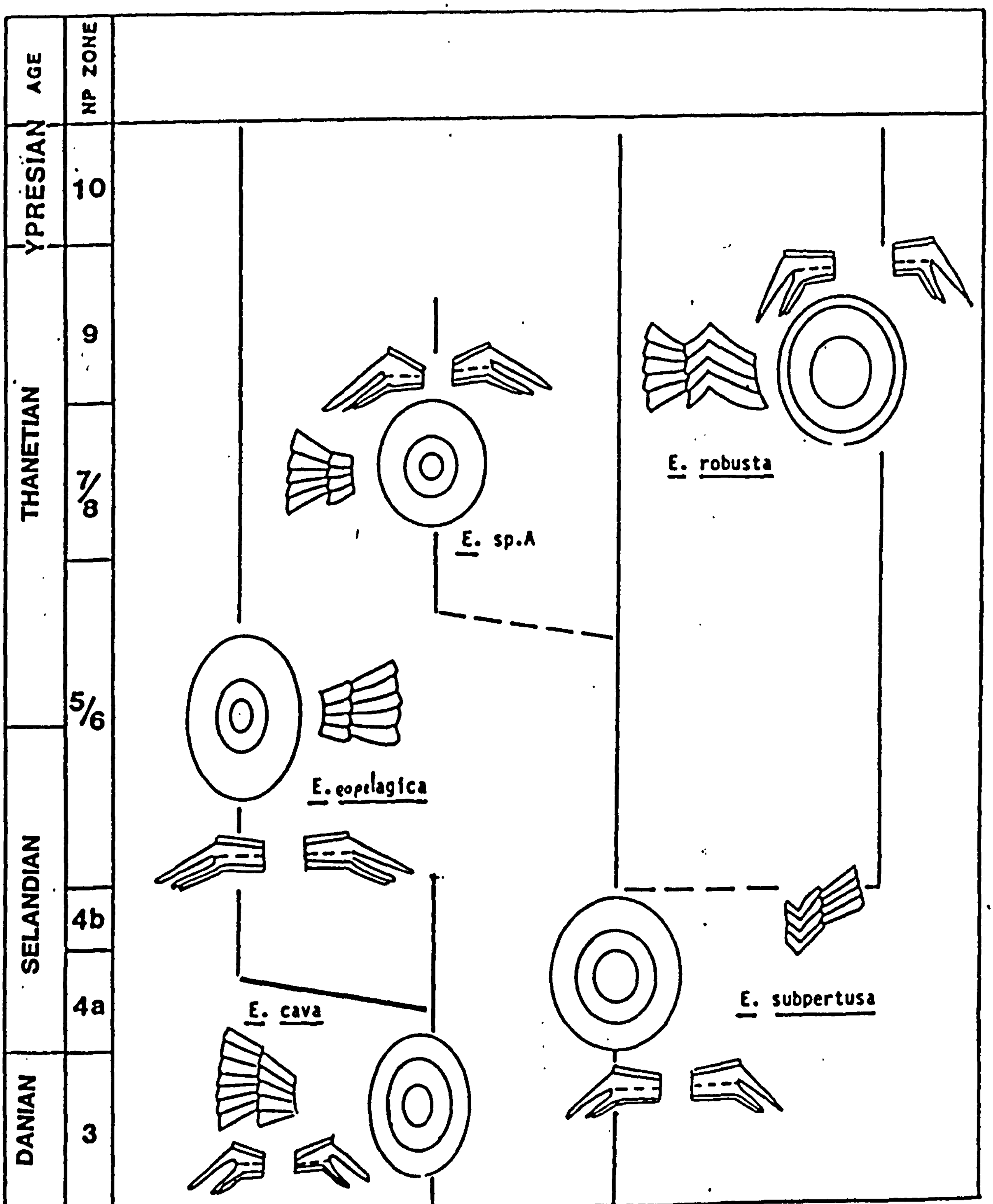


Fig.31 – Evolutionary lineages in the genus Ericsonia (based partly upon Romein 1979, figs. 35,36)

Ericsonia sp. A. appeared in NP5/6 at Gebel Um El Ghanayem section, Kharga Oasis and in Gebel Duwi section Quseir area. It is possibly evolved from E. subpertusa by reduction in the diameter (Diameter of E. sp. A. is 4 to 6 µm) and the more circular outline.

Ericsonia robusta is possibly evolved from E. subpertusa. The first appearance of E. robusta in Wadi Mellaha is in the Fasciculithus tympaniformis Zone (NP5/6). But in Um El-Ghanayem section and Gebel Duwi its first appearance is at the base of Discoaster Mohleri Zone (NP7/8). Romein (1979, p. 67 and 109) has mentioned that the first appearance of this species is in D. mohleri Zone (NP7/8). This species might have evolved from E. subpertusa at the base of the F. tympaniformis Zone (NP5/6) by an increase in the width of the wall, more outwardly steep distal shield (in distal view), the hook-shape of the sutures between the elements of the wall in distal view are getting away from the open central area to be nearer from the distal cycle of the distal shield and the outline is more circular (Fig. 31).

Lineages in the genus CHIASMOLITHUS (Fig. 32)

Lineages in this group have been described by Gartner (1970). He divided the species belonging to this genus into two groups on the basis of the construction of the crossbars of the central area. Romein (1979, p. 69) has agreed with Gartner's lineages and has considered that Chiasmolithus danicus,the first representative of Gartner's group II,had evolved from Cruciplacolithus edwardsii at the base of Cruciplacolithus tenuis Zone (equal to NP2 and NP3 in sense of Martini 1971), and Chiasmolithus consuetus which is the early representative of Gartner's group I is evolved from Cruciplacolithus primus. Perch-Nielsen (1985, p. 459 and 461) has considered Cruciplacolithus edwardsii to be the origin of both Chiasmolithus consuetus and C. danicus.

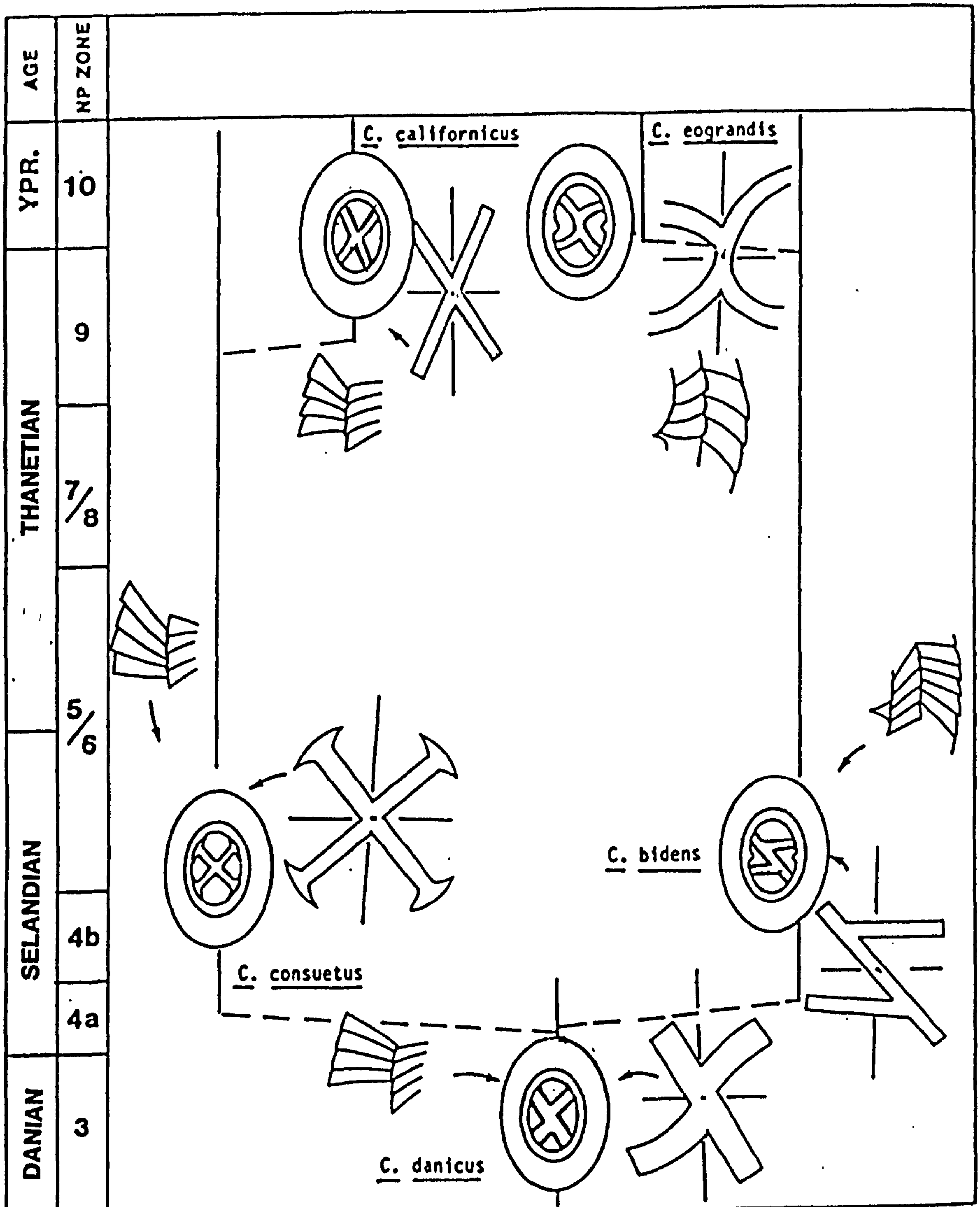


Fig.32-Evolutionary lineages in the genus Chiasmolithus (based upon Romein 1979, fig. 37)

In this study Gartner's lineage for this group is conformed to and my opinion about the origin of C. consuetus is discussed.

The species which are found and investigated in this work are:

1. Group I : Chiasmolithus consuetus, C. californicus
2. Group II : Chiasmolithus danicus, C. bidens, C. eograndis

In the light microscope, cross-polarised light, Group II show extinction lines splitting each bar of the central cross bars into two bright parts parallel to the long axis of each bar. The other group do not show this behaviour in the light microscope.

Generally C. danicus and C. californicus are rare but the other species of this genus are common.

Chiasmolithus consuetus is probably evolved from C. danicus because in the Gebel Duwi section at the top of the C. danicus Zone (NP3) and the base of Ellipsolithus macellus Zone (NP4a) samples 28 to 36 transitional forms which show crossbars slightly broader at their ends (like feet) are present. Chiasmolithus californicus is possibly evolved from C. consuetus (by the absence of the feet at the end of the crossbars) in the Discoaster multiradiatus Zone (NP9). This evolution relation is not seen as C. californicus is very rare and scattered in the NP9 and NP10 Zones of the studied areas.

Chiasmolithus bidens is probably evolved from C. danicus by the complete off-set of one of the central crossbars (the bar which is close to the short axis) until it become almost parallel to the short axis of the ellipse and the presence of very small tooth-like projections extending from the wall into the central area (Fig.32).

Romein (1979, p. 69) has mentioned that he found, in sections from Scandinavia, in the E. macellus Zone (=NP4a and NP4b, this work) intermediates between C. danicus and C. bidens. He also suggested that C. bidens is probably evolved from C. danicus in boreal waters and migrated afterwards to warmer water. In Egypt C. bidens enters suddenly at the top of the E. macellus Zone. C. bidens is a possible ancestor to C. eograndis, this is because rare forms of C. bidens at the top of D. multiradiatus Zone (NP9) in Gebel Atshan, Quseir area, (sample 26) start to have off-set bars which are slightly curved clockwise on the distal side (Fig. 33). At the base of Tribrachiatus contortus Zone (NP10), in Gebel tarbouli, C. eograndis starts to appear with its distinctive curved crossbars; one bar is slightly off-set and slightly curved anticlockwise in distal view and the other is strongly off-set and curved clockwise in distal view as well.

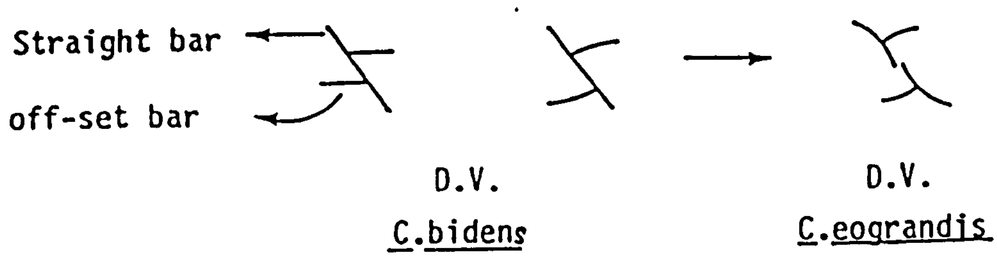


Fig.33 -Schematic drawings showing the changes in the orientation of the central crossbars (of the central area) in the development of Chiasmolithus eograndis from C.bidens

Lineages in the genus NEOCHIASTOZYGUS (Fig. 34)

Perch-Nielsen (1981a, p. 845) has suggested an evolution scheme for the species belonging to this genus. Also in (1985, p. 527-531) she discussed the species in the order in which they appear. In this work her suggested evolutionary lineage is discussed according to my observations and investigations of the Neochiastozygus species which have been detected and another idea about the origin of N. distentus and N. junctus is suggested. In the Palaeocene and the Lower Eocene (Ypresian) of Egypt only five species of genus Neochiastozygus are found. Neochiastozygus concinnus is generally common in the Early Tertiary samples. Neochiastozygus perfectus, N. modestus, N. distentus and N. junctus are generally rare.The first species to appear in (Gebel Duwi section) the C. danicus Zone (NP3) is N. modestus. At the top of NP4a Zone N. concinnus is suggested to be evolved from N. modestus by the decrease in the width of the cross bars (of the central area) near the intersection and the increase of their width near the margin. The angles they make with each other remains more or less the same as in N. modestus.

The first appearance of N. concinnus was detected by Romein (1979, p. 136) in the F. tympaniformis Zone (NP5) and Perch-Nielsen (1981a, Fig. 1) in the E. macellus Zone (NP4). In Egypt, Gebel Duwi, the first appearance of this species is detected in the top of NP4a. Neochiastozygus perfectus is probably evolved from N. modestus at the upper part of NP4a Zone by the decrease of the angle which the crossbars of the central area make with the short axis of the ellipse and an increase in the width of the margin. Also Perch-Nielsen suggested that N. perfectus evolved from N. modestus probably in the later part of NP4 Zone. In her evolutionary lineages (1981a, p. 845) N. perfectus and N. concinnus first appear at the same time in the top of NP4. N. modestus is probably the ancestor of N. distentus. The latter species is evolved from the former one in the F. tympaniformis Zone NP5/6 (Gebel Um El Ghanayem) by increasing the width of the margin and decreasing the diameter of the central area. Neochiastozygus perfectus (length 6-9 µm) is very rare in the Upper Palaeocene of Gebel Duwi and Gebel Atshan. In the D. multiradiatus Zone (NP9) forms similar to N. perfectus but different in their

larger diameter (length 9.5-12.5 µm) and broader central area start to appear.
These forms are known as N. junctus which continue in the Lower Eocene. Perch-Nielsen has considered that N. cearae is the

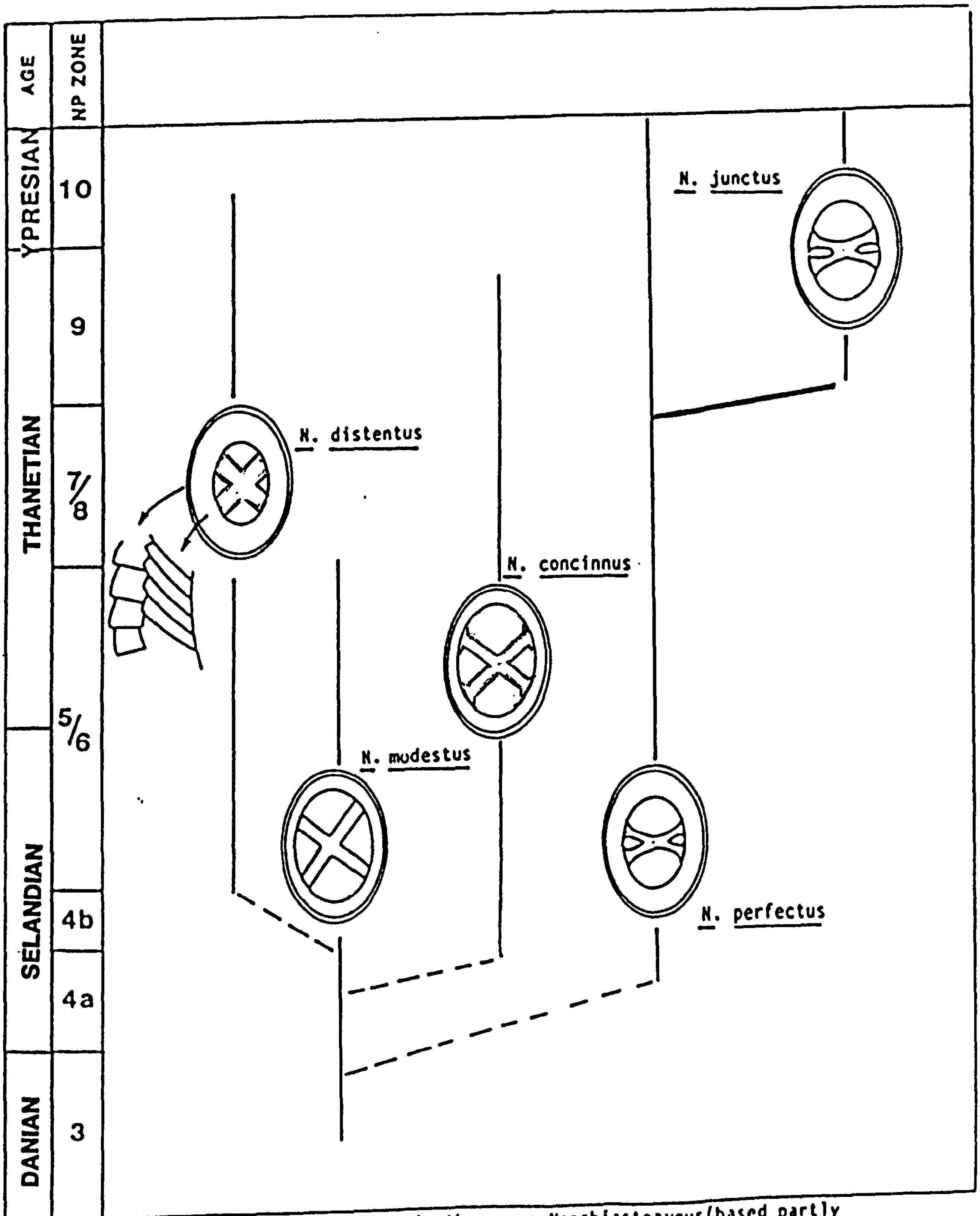


Fig.34 - Evolutionary lineages in the genus Neochiastozygus (based partly upon Perch-Nielsen 1981a, fig.1)

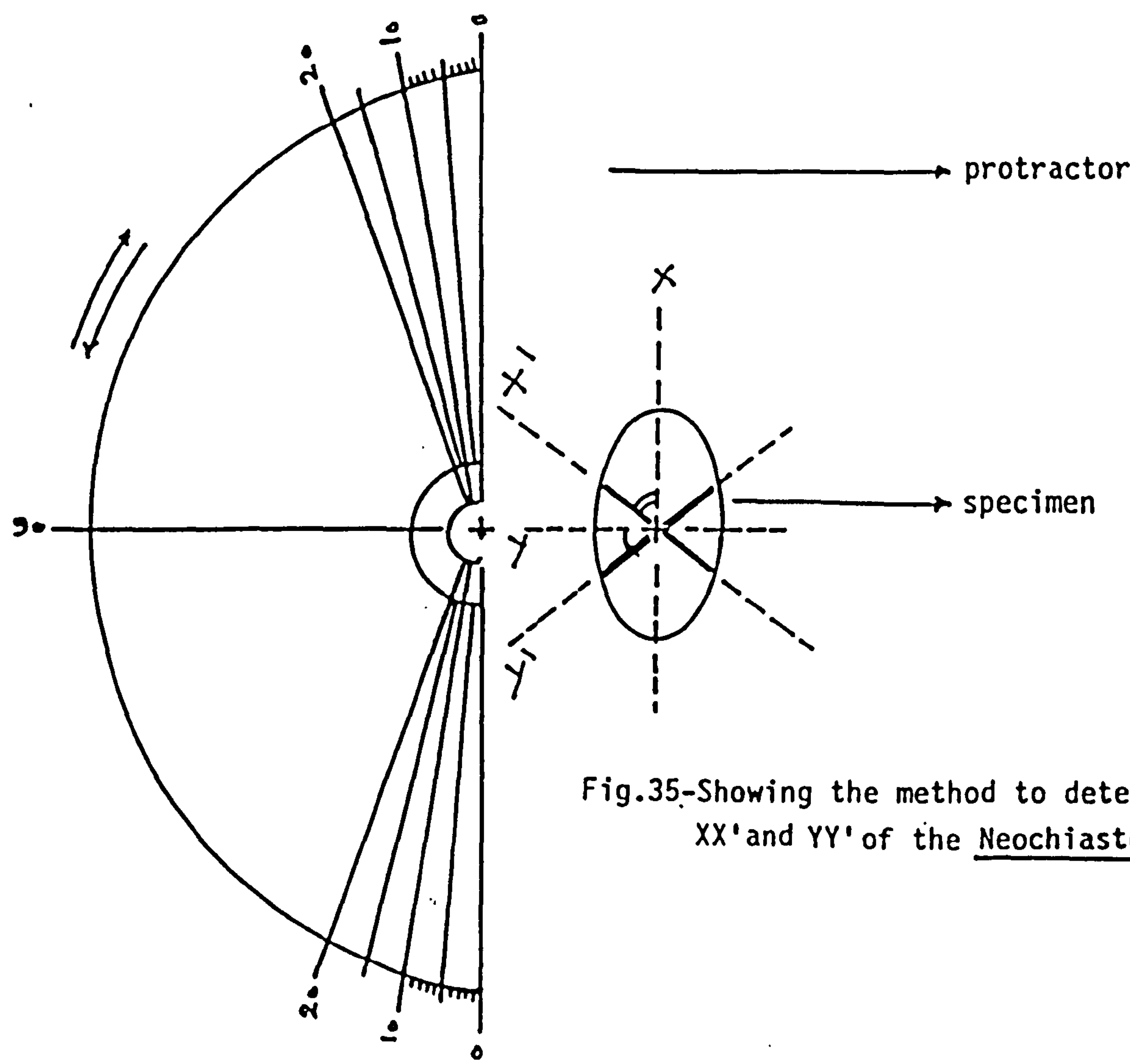


Fig.35-Showing the method to determine the angles XX' and YY' of the Neochiastozygus specimens

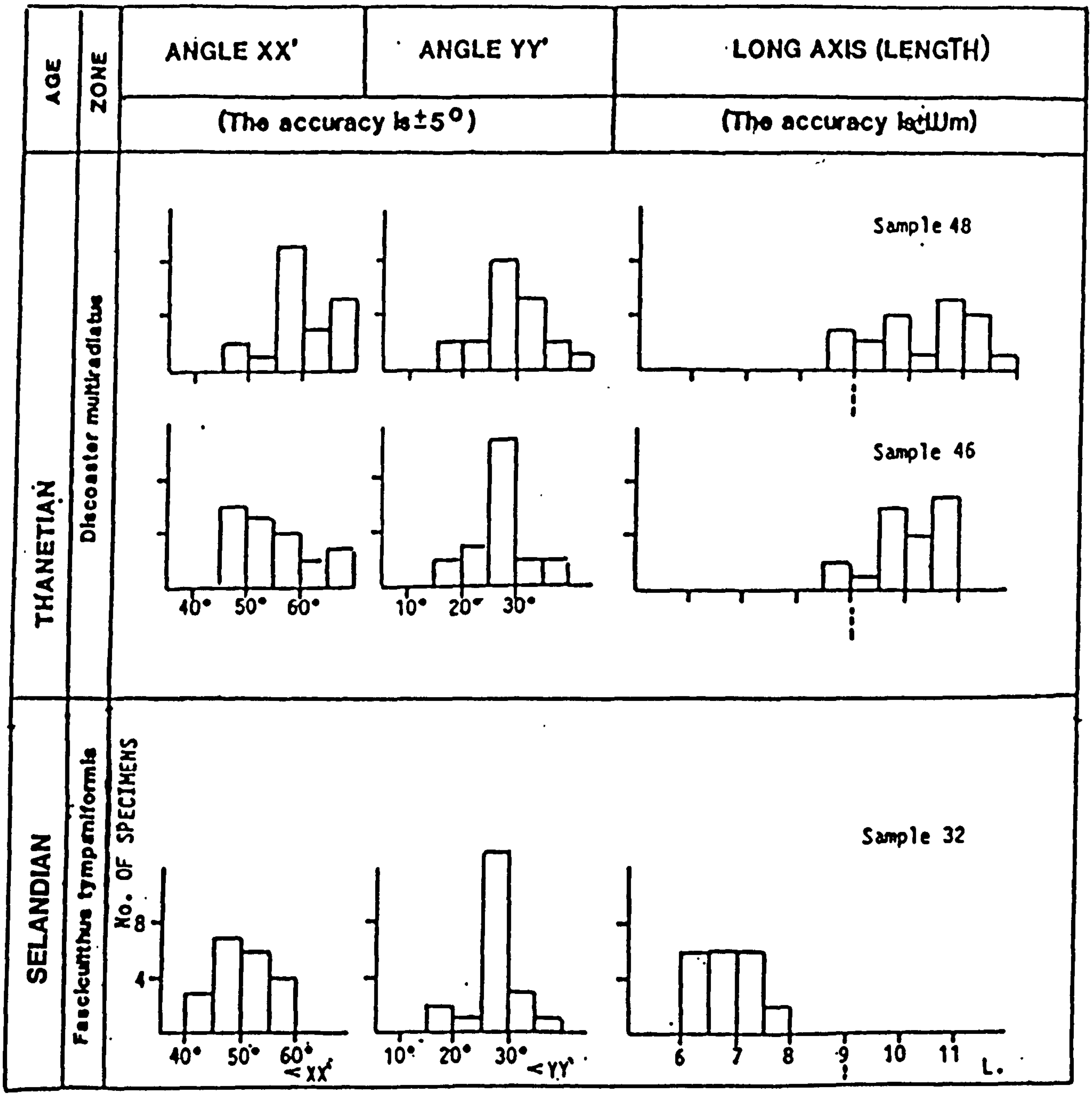


Fig. 36-Histograms showing the increase of the length (L.) from N. perfectus to N. junctus in the F. tympaniformis to D. multiradiatus Zone in Gebel Um El Ghanayem section. The angle XX' is more than 60° for some specimens of N. perfectus (in D. multiradiatus Zone) and N. junctus.

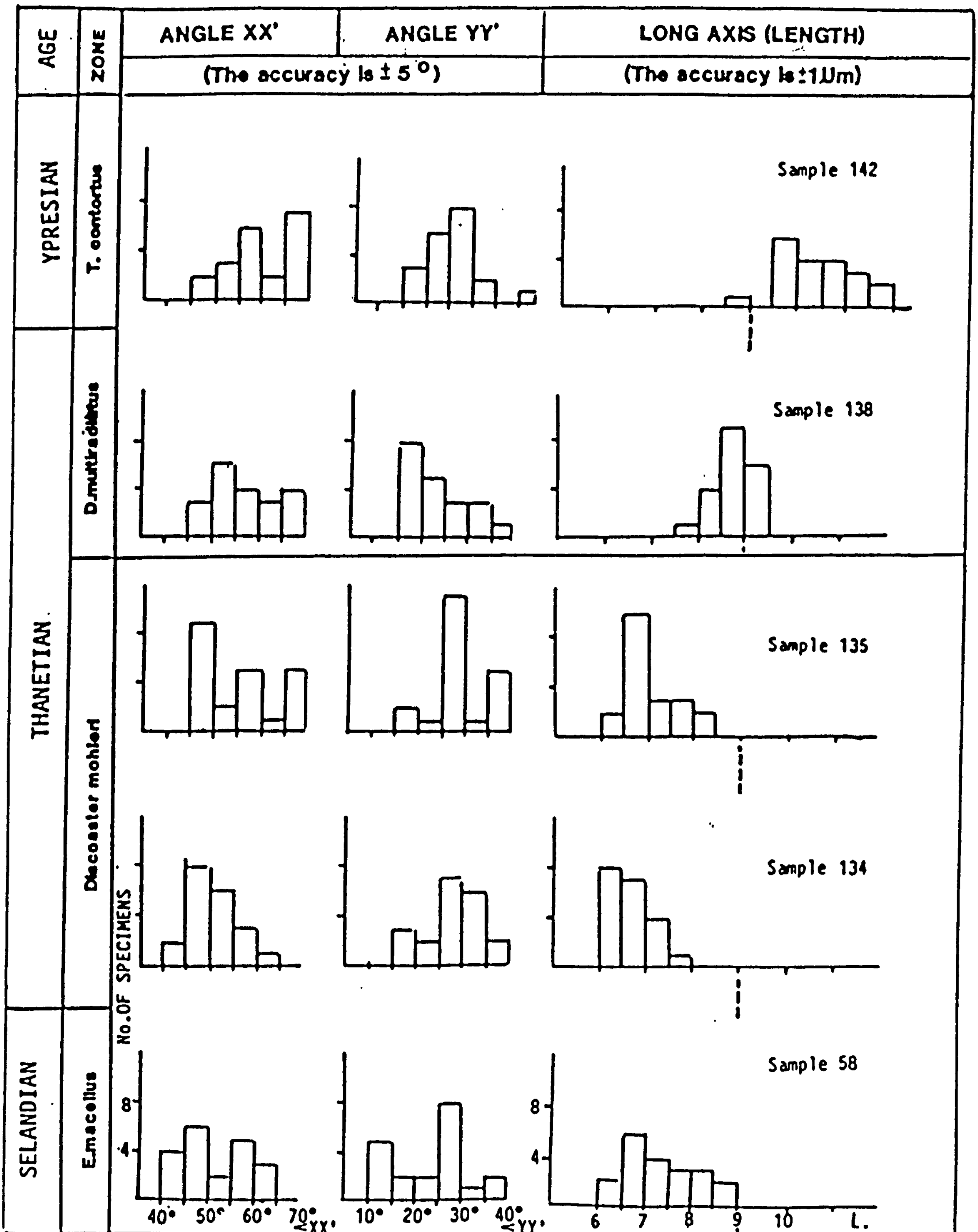


Fig.37 Histograms showing the increase of length (L.) from N. perfectus to N. junctus through the Palaeocene in Gebel Duwi section. The angle XX' is more than 65° for some specimens of N. perfectus (in younger assemblages) and N. junctus. No significant change in the angle YY'.

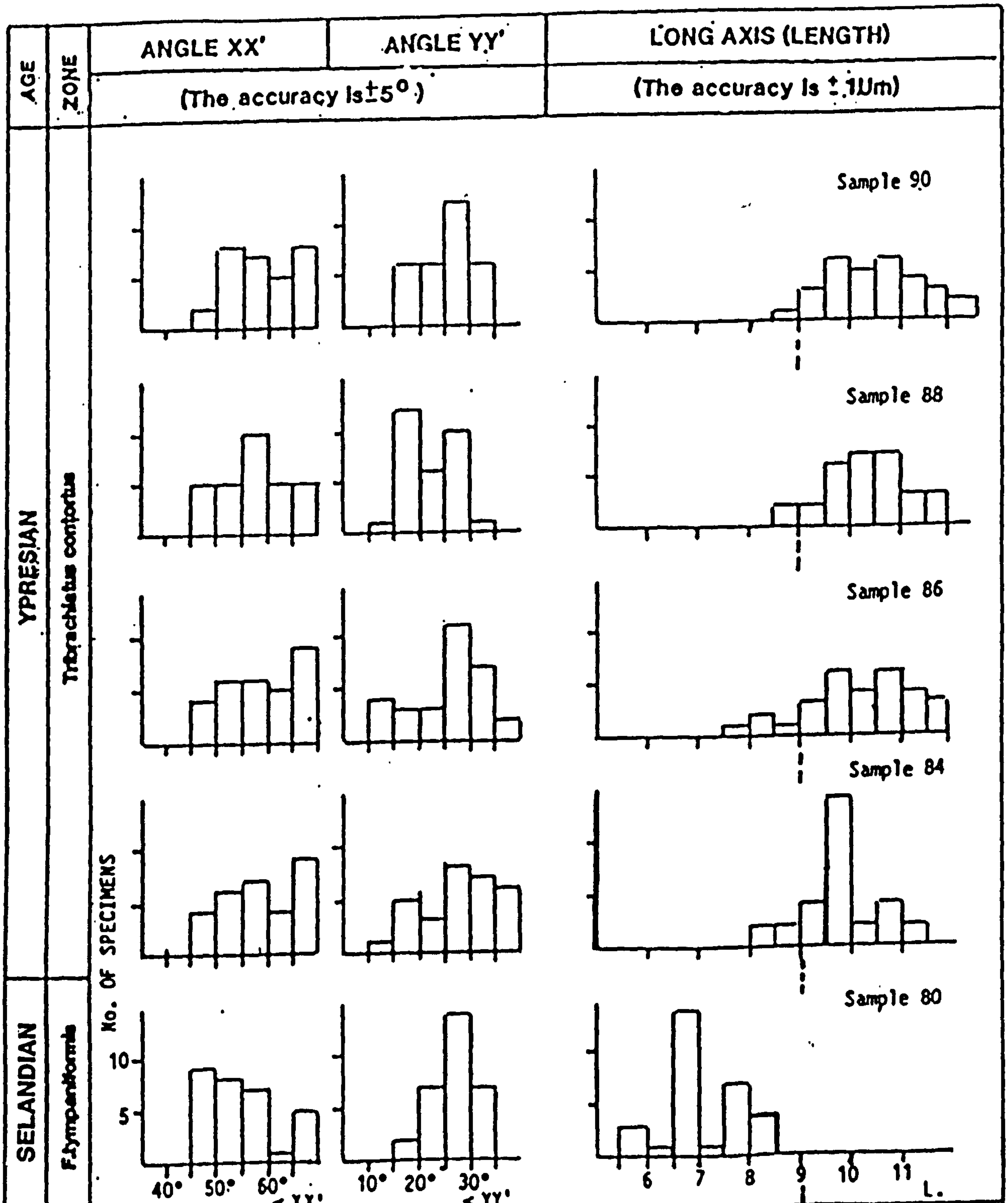


Fig 38 - Histograms showing the increase of length(L.) from Neochiastozygus perfectus to N. junctus in the Thanetian - Ypresian interval of Wadi Mellaha section. No significant change in the angles XX' or YY' ancestor of N. junctus as the stratigraphic range of the former species overlaps with the latter one, while in her diagram the last occurrence of N. perfectus does not. The stratigraphic range of the above mentioned three species differ in Romein (1979) and Perch-Nielsen (1981a) and in this work. Also N. cearae is not seen in the studied sections.

Measurements of the length and the angles between the cross bars of the central area and the major axes of the ellipse in some specimens of Neochiastozygus perfectus and N. junctus has been carried out (Figs. 36, 37, 38). Selected samples from Wadi Mellaha, Gebel Duwi and Gebel Um El Ghanayem sections were used for this purpose. The poor preservation, rare occurrence and the discontinous presence of these species (and also the other members of the Neochiastozygus group) in the Early Tertiary sediments make these measurements from stratigraphically closely spaced samples impossible. The following parameters are measured (using the light microscope, cross-polarised light):

1. the length (the long diameter)
2. the angle between the x-bars and the x-axis of the ellipse ($< xx'$)
3. the angle between the y'-bars and the y-axis of the ellipse ($< yy'$)

For specimens lying flat the working procedure for measuring the angle xx' and yy' is (Fig. 35):

1. the centre of the specimen (the point of intersection of the cross bars) is located on + sign of the protractor (the protractor is located between the eye-piece and the optovar)
2. the reading of the protractor for x'-bar gives the angle xx' ($< xx'$)
3. for measuring the angle yy' take the reading for y'-bar on the protractor then the angle yy' = 90°–y'-bar reading

Five samples from Gebel Duwi section are selected to measure the length and the angles xx' and yy' (twenty specimens from each sample). The range of length is from 6 to 9 μm in samples 58, 134, 135, while in the younger samples 138, 142 the range of length is from 8 to 12 μm. A rapid increase in length is observed in the D. multiradiatus Zone and T. contortus Zone. The angle yy' does show any significant changes through time. More specimens have the angle xx' over 65° in sample 135, 138, 142.

From Wadi Mellaha section five samples are selected (thirty specimens from each sample) for this study (Fig. 38). The range of length of the specimens in the sample 80 is from 6 to 8.5 μm. In samples 84, 86, 88, 90 the range of length is from 8 to 12.5 μm. No significant changes in the angles xx' and yy' except that samples 84, 86, 90 has more specimens with a larger xx' angle (between 55° and 70°) and smaller yy' angle (between 10° and 25°) compared to those of sample 80. Three samples from Gebel Um El Ghanayem section (fifteen specimens from each sample) are found to be suitable to measure the above mentioned parameters (Fig. 36). In sample 32 the range of length is from 6 to 8 μm while its from 8.5 to 12 μm in samples 46, 48. Some specimens have an angle xx' over 60° in samples 46, 48 while in sample 32 the angles xx' is 60° or less.

Conclusion:

The following conclusions can be drawn:

1. the length of the measured specimens increases in progressively younger assemblages (in the D. multiradiatus Zone and T. contortus Zone). Neochiastozygus perfectus is restricted to specimens with length from 6 to 9 μm and N. junctus to specimens with length from 9.5 to 12.5 μm.

2. no significant changes in the angles xx' and yy'. Generally, more specimens have a large xx' angle (between 55° and 70°) and small yy' angle (between 10° and 25°) in younger assemblages (in the D. multiradiatus Zone and T. contortus Zone) than those of older assemblages (in the F. tympaniformis Zone and E. macellus Zone).

Unfortunately there is stratigraphic gaps between the samples used in this study, this is due to the rare occurrence and/or the poor preservation of assemblages in the samples between those used for the measurement) thus making them unsuitable for study.

Lineages in the Genus DIADOCHIASTOZYGUS (Fig. 39)

The members of this group were treated by Perch-Nielsen (1981a, p. 845 and 846) as species belonging to Neochiastozygus group and included them in her evolutionary lineages. In this project this group is treated as a separate one. This is because they have different margin construction and a more restricted stratigraphic range compared to the Neochiastozygus group. Another opinion about their evolution relation is suggested and discussed below.

The members of this group are Diadochiastozygus imbriei, D. eosaepes and D. saepes. These species are rare in Egypt. They are more common in Gebel Duwi section, Quseir area. Diadochiastozygus imbriei is the oldest representative of this genus. Perch-Nielsen (1981a) has mentioned that Neochiatozygus eosaepes (=Diadochiastozygus eosaepes) is the oldest species as it first appeared in the middle of NP3 while Neochiastozygus imbriei (=D. imbriei) first appeared in the top of the same zone. In Wadi Tarfa section, D. imbriei is found in NP3 Zone while in Gebel Duwi section, the three species of the Diadochiastozygus group where found in the E. macellus Zone (NP4a).

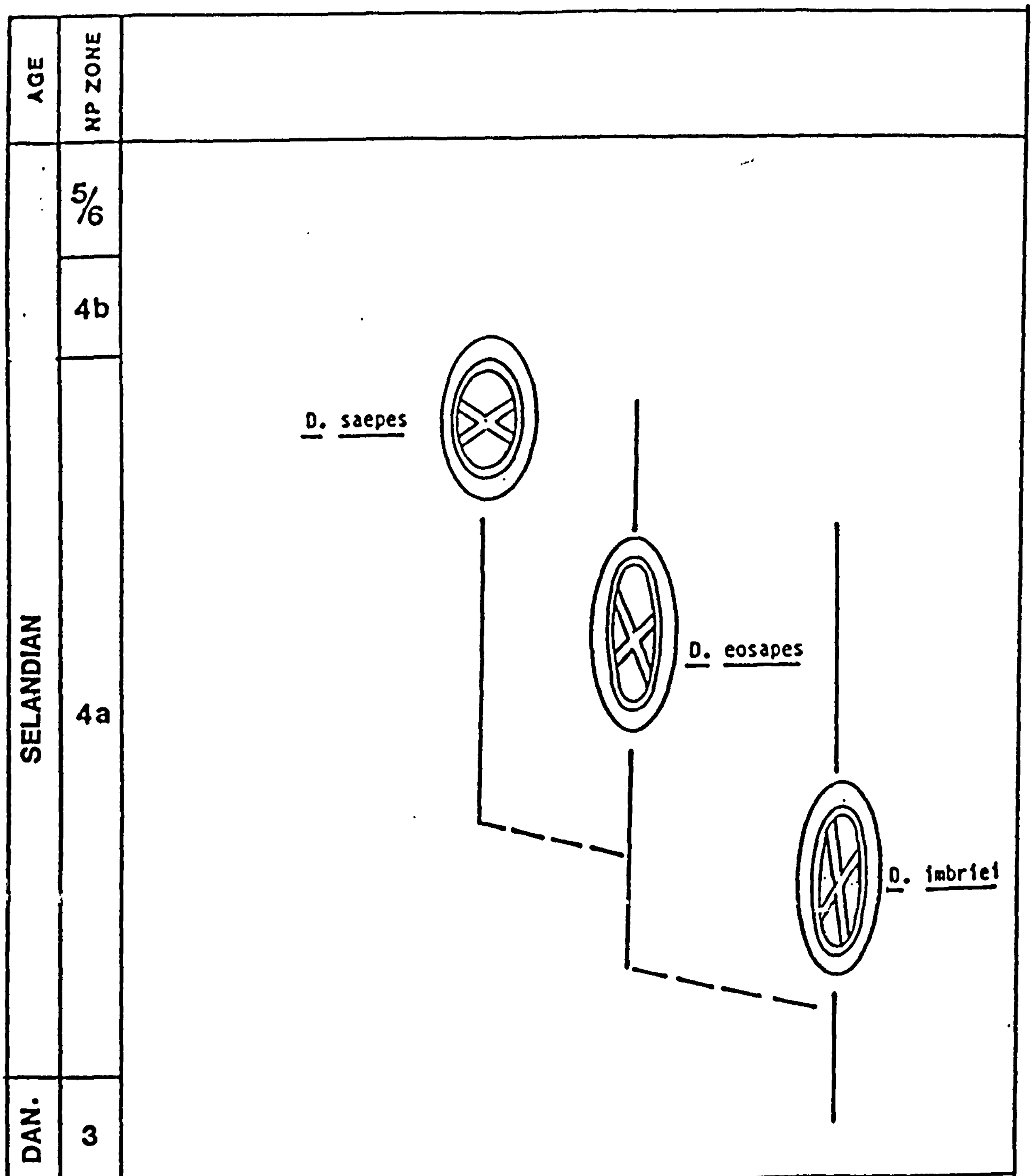


Fig.39-Evolutionary lineages in the genus Diadochiastozygus (based partly upon Perch-Nielsen 1981a,fig.1)

Diadochiastozygus eosaepes could have derived from D. imbriei by the reduction of the length of the long bar and the increase in the angle which the long bar of the central area makes with the long axis of the ellipse in an anticlockwise direction in distal view. The above mentioned angle becomes more, the cross bars of the central area become equal in length and the outline gets more elliptical in D. saepes in a higher level in the E. macellus Zone (NP4a).

Lineages in the genus FASCICULITHUS (Figs. 40, 41)

Romein (1979, p. 76 and 77) has proposed evolutionary lineages for the species of the genus Fasciculithus. Here I have applied his suggested evolution relations to the Fasciculithus species found in Egypt, new species F. ragaae and F. gelelii are included, and another opinion about the origin of F. billii, F. janii, F. involutus and F. alanii is discussed.

Fasciculithus ulii, F. tympaniformis, F. bobii and F. involutus are generally common in Egypt while F. ragaae., F. gelelii, F. billii, F. janii, F. tonii, F. schaubi and F. alanii are rare.

Fasciculithus ulii is the first to represent this group in the Ellipsolithus macellus Zone (NP4a). This species could be the ancestor of F. ragaae by the increase of the diameter of the median cycle (this cycle becomes larger than the diameter of the column in F. ragaae) and the height of the cone. Fasciculithus gelelii is a large form (height: 10-15 µm, diameter: 8-12 µm) which might originate from F. ragaae by flaring of the two far ends outwards.

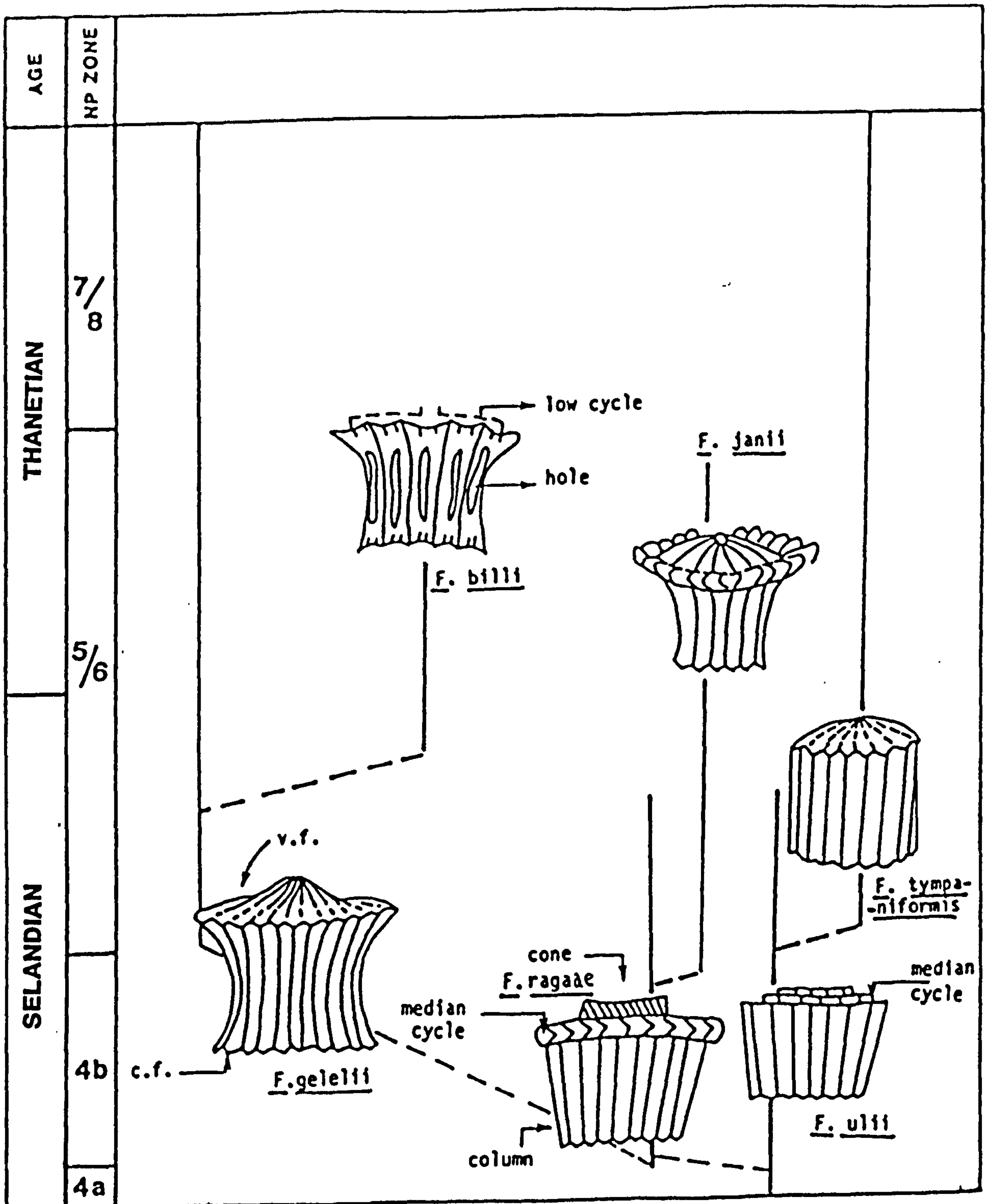


Fig.40-Evolutionary lineages in the genus Fasciculithus (based partly upon Romein 1979, fig. 40)

v.f. = convex face
c.f. = concave face

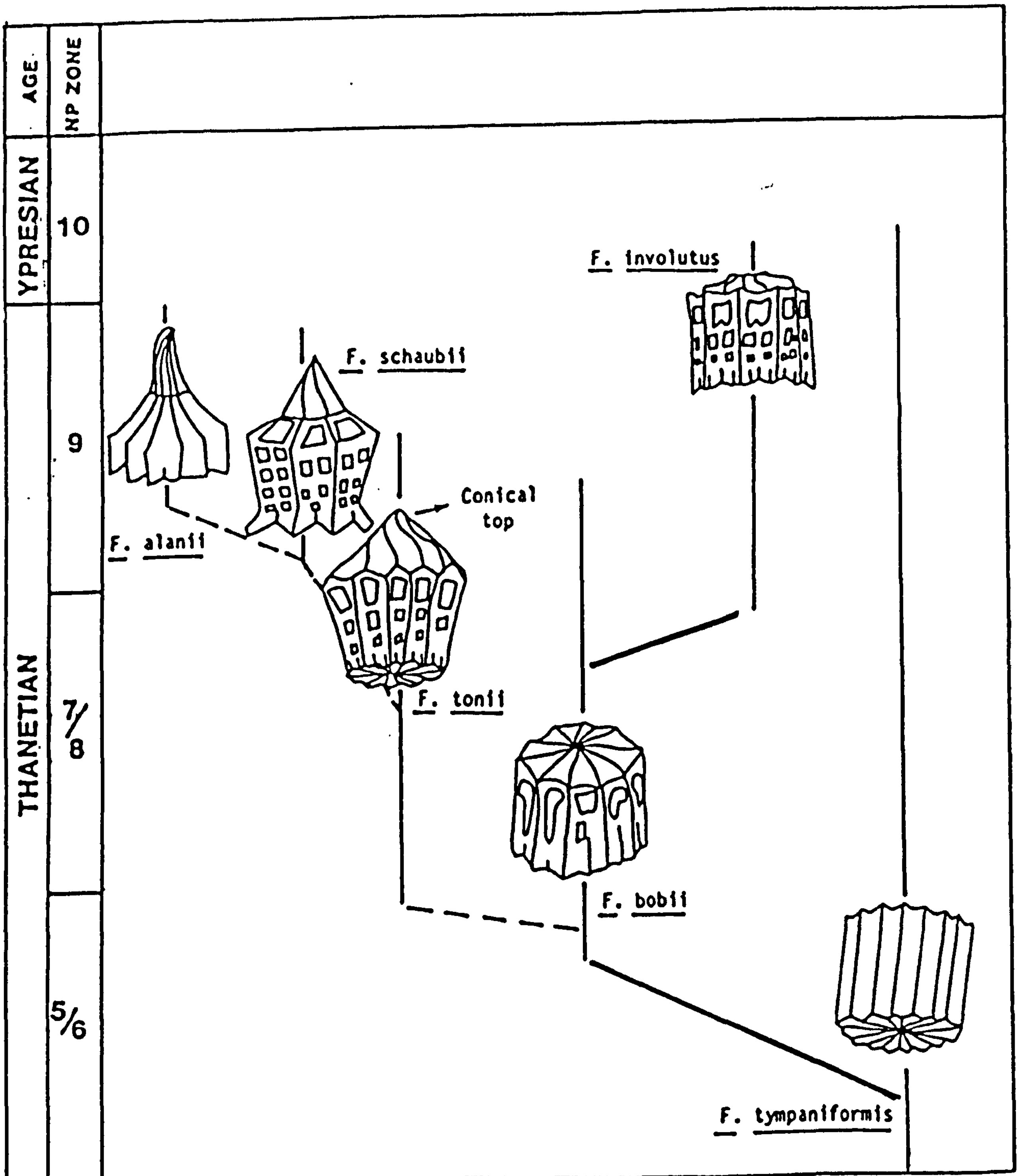


Fig.41 - Evolutionary lineages in the genus *Fasciculithus* (based partly upon Romein 1979, fig. 40)

Due to the poor preservation state of the specimens of this species I could not observe what has happened exactly to the upper part of the convex face. It seems in this evolution from *F. ragaae* to *Fasciculithus gelelii* the median elongated cycle becomes very reduced and the top part becomes conical in shape. *Fasciculithus gelelii* is considered to be the ancestor of *F. billii* by the absence of the pointed cone and the presence of low cycle on the convex face and elongate holes along the column. *Fasciculithus janii* could be derived from *F. ragaae* by the development of dome-like top instead of the cone top of *Fasciculithus ragaae*. *Fasciculithis tympaniformis* could be derived from *F. ulii* by the disappearance of the median cycle, and the cone becomes more convex. The younger *Fasciculithus* species which started to evolve in the top of *F. tympaniformis* Zone NP5/6 (from *F. bobii*) are distinguished by the presence of holes in the column and the star-like shape in plain view for most of them, the others having a rossette-shape instead. *Fasciculithus bobii* has evolved from *F. tympaniformis* by the presence of cycle of small holes near the convex face. Forms with undeveloped holes in NP5/6 Zone, and the base of NP7/8 Zone in Gebel Duwi section are found and considered to be transitional forms. *Fasciculithus bobii* is the ancestor of *F. involutus* by the presence of more than one cycle of holes in the outer surface of the column (from two to four cycles). *Fasciculithus involutus*'s earliest appearance in Gebel Duwi is in the top of NP7/8 Zone and Gebel Atshan is in the base of NP9 Zone. Intermediate forms in sample 20 (NP9) of Gebel Atshan and sample 139 (NP9) of Gebel Duwi are observed. These intermediate forms show an undeveloped or ill differentiated second cycle of holes around the column. *Fasciculithus tonii* probably evolved from *F. bobii* by the development of the convex part into a conical protrusion with slightly twisted top and the increase of the cycles of holes around the column (from 2 to 4 cycles). *Fasciculithus schaubii* has a more tapering end (convex side) than *F. tonii* and the arrangement of the holes around the column is more complicated. *Fasciculithus alanii* also has a more tapering end (convex side) than in *F. schaubii* and *F. tonii*. Also there is a general trend for these species to increase the free part between the elements forming the column, thus giving the species the star-like shape in plane view instead of the rosette-like shape of the older forms.

Lineages in the genera HELIOLITHUS and BOMOLITHUS (Figs. 42, 43)

Romein (1979, p. 78 and 79) has suggested lineage relations for these groups. These evolution relations are observed in my sections particularly in Gebel Duwi, Quseir area. Another opinion about the origin of *Bomolithus megastypus* is suggested and the evolution relation between *Discoaster drieveri* and *Bomolithus elegans* is discussed here.

The species included in the evolution relations are *Bomolithus cantabriae*, *B. elegans*, *B. megastypus*, *Discoaster drieveri*, *Heliolithus kleinpellii* and *Heliolithus riedelii*. The latter three species are rare while the others are common in the Upper Palaeocene samples.

The earlier representatives of this genus are *Bomolithus elegans* and *B. cantabriae*. These two species first appear in the upper part of *F. tympaniformis* (NP5/6) at Gebel Duwi section sample number (100). Each one of these species is considered to be the origin of a group of younger species. *Bomolithus megastypus* is evolved from *B. elegans* by the reduction of the diameter of the outer cycle, increase in the diameter of the median cycle and becomes more or less flat compared to the steeply outward sloping median cycle of the latter species. The diameter of the median cycle of most of *B. megastypus* is twice (or more) the diameter of the column, while the diameter of the median cycle of *B. elegans* is less than twice the diameter of the column (Table 4).

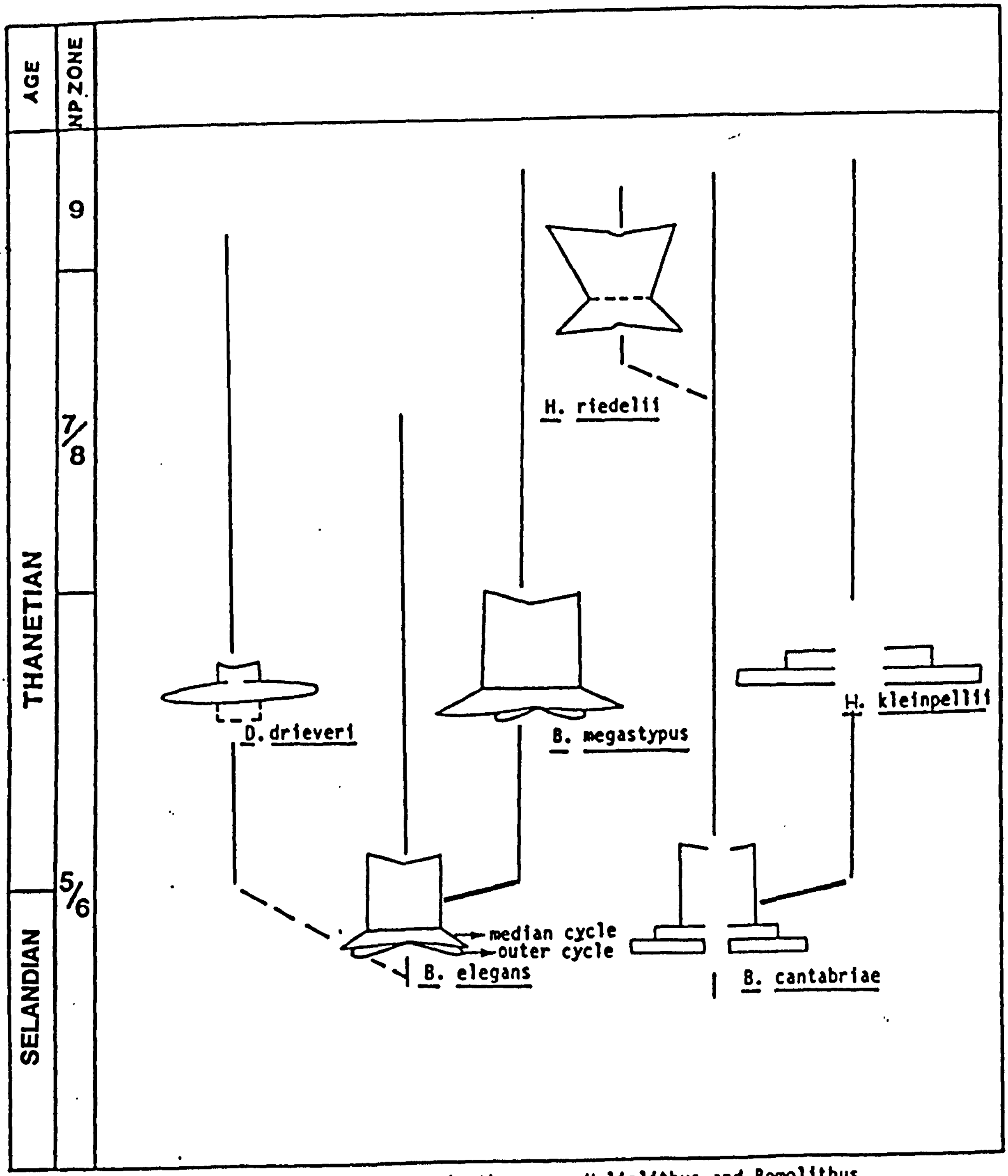


Fig.42-Evolutionary lineages in the genus Heliolithus and Bomolithus (based partly upon Romein 1979, fig.41)

B. = Bomolithus
D. = Discoaster
H. = Heliolithus

B. elegans	Median= Cyc.	7.2	8.7	7	8	8.2	7	9	8	6	8	9	8.5	7.5	7.1	7	μm
	Column	4	6	5	6	4.9	4.5	5	5.1	3.8	5.8	6.1	6	5	5	4.8	μm
B. megastypus	Median Cyc.	7.1	8.6	9	8	8	7	7.5	9	7	8.5	7.9	9	8.7	8	9	μm
	Column	3	3.9	4	4	4	3.6	3.4	4.3	3.2	4.1	3.3	4.2	3	3.5	4.3	μm

Table 4 - Measurements for the diameters of the median cycle and the column of Bomolithus megastypus and B. elegans of some specimens from Gebel Duwi samples 100, 101, 102, 107, 108 (NP5/6) and Wadi Tarfa sample 61 (NP5/6).

Forms with transitional characters between Bomolithus elegans, Discoaster drieveri and Bomolithus megastypus are found in sample 102 (base of NP5/6) Gebel Duwi section. Romein (1979, p. 79) has mentioned that B. megastypus evolved from B. cantabriae in the Discoaster mohleri Zone (NP7/8). In Gebel Duwi section, Quseir area, B. megastypus first appears in the middle part of NP5/6 Zone and no transition forms between the above mentioned two species are seen. Heliolithus kleinpellii evolved from B. cantabriae at the upper part of NP5/6 Zone by a decrease in the column height, an increase in the diameter of the outer cycle and an increase in the diameter of the central opening (the diameter of the outer cycle of H. kleinpellii is 10-14 μm, the diameter of the outer cycle of B. cantabriae is 7-11 μm). Heliolithus riedelii may be evolved from Bomolithus cantabriae by the flaring out of the column and the disappearance of the median cycle (Fig. 43).

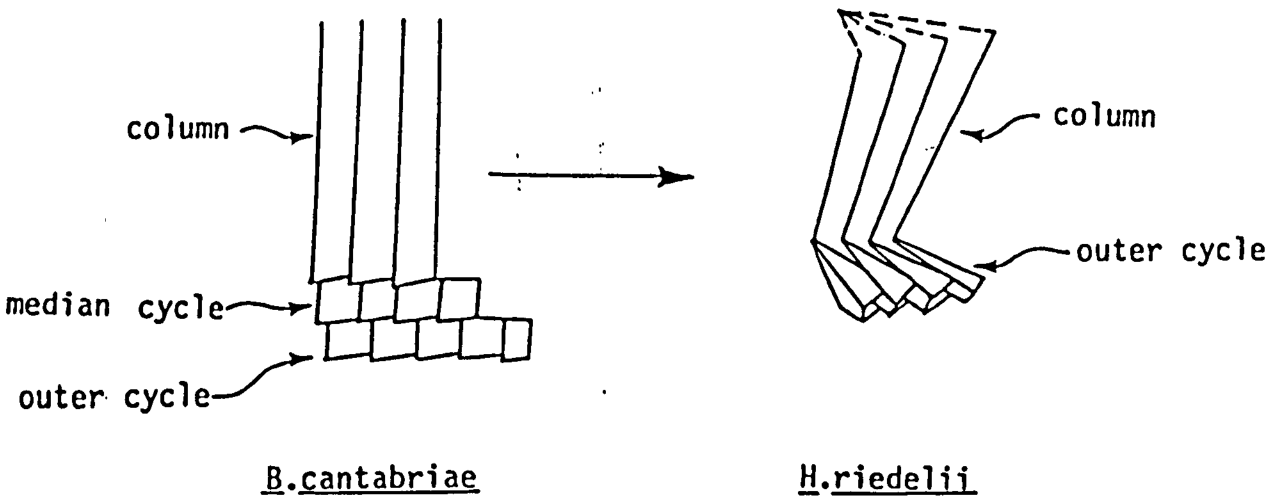


Fig.43-Schematic drawings showing the changes in morphology in the development of Heliolithus riedelii from Bomolithus cantabriae

The origin of DISCOASTER MOHLERI AND BOMOLITHUS MEGASTYPUS (Fig. 44)

Romein (1979, p. 79 and 80) has explained the lineages from B. elegans to Discoaster drieveri in the upper part of Heliolithus kleinpellii Zone NP6 (= the upper part of NP5/6, this work) and then the evolution from the latter species to D. mohleri in the base of Discoaster mohleri Zone (NP7/8). He also mentioned that D. drieveri shows a large variation in the structure of the centre. In Gebel Duwi section Discoaster driveri is found very rare at the upper part of the NP5/6 Zone. Investigating the early Discoaster forms the upper part of the F. tympaniformis Zone NP5/6 (equal NP6) using the light microscope and the scanning electron microscope show another two forms Discoaster atefii and D. duwiensis which may be considered before as belonging to D. drieveri. These two species differ from D. drieveri by the absence of a short column on the

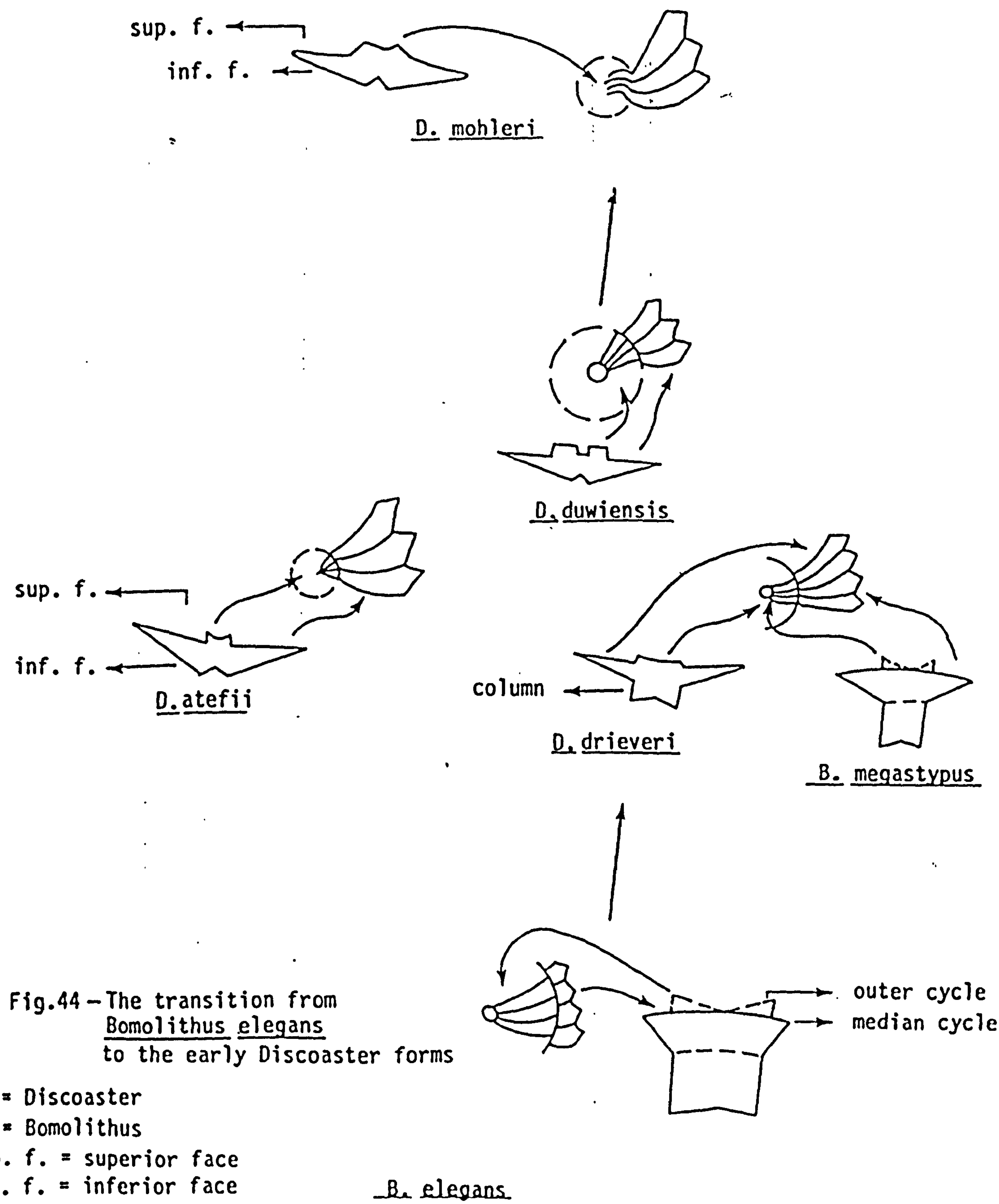


Fig.44 – The transition from *Bomolithus elegans* to the early Discoaster forms

D. = Discoaster
B. = Bomolithus
sup. f. = superior face
inf. f. = inferior face

inferior face (Fig. 44). Bomolithus elegans may be the ancestor of these early Discoaster forms by the reduction of length or disappearance of the column and the outer cycle and the increase in diameter of the median cycle. The same transformation is thought to be happened from Bomolithus elegans to B. megastypus except the column still has more or less the same length. The ancestor of Discoaster mohleri is not clear but probably from one of these early Discoaster species (D. drieveri, D. atefii, D. duwiensis).

Lineages in DISCOASTER group (Figs. 45, 46, 47)

The Discoaster group includes the calcareous nannofossils of star or rosette shape. The species belonging to this group evolved rapidly through the Tertiary. Bukry (1971) discussed an evolutionary trend toward a less massive skeleton in the Discoaster species through the Tertiary. Prins (1971) presented a detailed study of the morphological evolution of this group. Romein (1979) investigated the Early Palaeogene discoasters. He differentiated two major groups based on the optical pattern of the asteroliths. Group I for those discoasters without a regular extinction cross between cross-nicols and the ancestor of this group is D. bramlettei (=D. drieveri). Group II for those discoaster with a regular extinction cross between cross-nicols and the ancestor is Bomolithus megastypus. Theodoridis (1984) divided the discoaster species of the Tertiary into two genera. The asteroliths of Helio-discoaster have curved, hook-shaped or subradial sutures and are the dominant forms of the Palaeogene, whereas the asteroliths of Eu-discoaster have straight and radial sutures and are confined to the Neogene (with the exception of E. deflandrei, E. nonaradiatus and E. distinctus). Also in the same year page 139 figures 65 and 66 he arranged the discoaster species of the Palaeogene and the Neogene in groups based on morphological similarities.

A comprehensive investigation of lineage relationships between Palaeocene and Lower Eocene Discoaster species from Egypt were carried out in this research. The relations suggested below largely conform to those proposed by Romein (1979), a different opinion about the origin of Discoaster Group II (with a regular extinction cross between cross-nicols) and D. binodosus is expressed. Discoaster salisburgensis is included in the lineages of Discoaster Group II and its origin is discussed. Discoaster mahmoudii and D. okadai are found but their origin is still obscure as no link between them and the other asteroliths is observed. The new species Discoaster amrii is included and considered to be evolved from D. mohleri.

The discoaster species in the Lower Tertiary of Egypt are generally common except Discoaster lenticularis, D. okadii and D. amrii.

Two groups of asteroliths with two different lineages are detected. These groups are,

1) Group I : The members of this group are Discoaster mohleri, D. mediosus, D. amrii, D. nobilis, D. ornatus and D. binodosus

2) Group II : The members of this group are, Discoaster multiradiatus, D. lenticularis, D. salisburgensis, and D. diastypus.

Group I show a general trend through the Lower Tertiary of:

1) Increase of the curvature of the sutures between the rays (or arms) on one side. Also these sutures are more deeply incised in younger forms

2) Increase in the free parts of the rays

3) Decrease in the number of rays (or arms)

Group II show a general trend through the Lower Tertiary of:

1) Increase in the diameter and the length of the central stem

2) The tips at the ends of the rays are more pointed in younger species

3) The number of rays are less in younger forms

Discoaster mediosus may be evolved from Discoaster mohleri in the D. mohleri Zone (NP7/8) by the presence of more free outer parts of the rays and the tips become rounded with parallel sides. This species first appeared suddenly in NP7/8 Zone in Gebel Duwi and no intermediate forms between this species and D. mohleri are observed. Transitional forms between D. mohleri and D. nobilis are observed in Gebel Atshan section samples 20, 22, which represent the lower part of the D. multiradiatus Zone (NP9). This evolution happened by the change of the shape of sutures of D. mohleri on the superior face from curved to hook-shaped and more deeply incised. Discoaster amrii is evolved from D. mohleri by the increase of length of the free parts of the rays, the sutures on the superior face becomes hook-shaped and very deeply incised and a low central cone at this side is formed. Intermediate forms between D. mohleri and D. ornatus are seen at the top of D. multiradiatus Zone in Gebel Duwi and Gebel Atshan sections. These forms show rays with variable length of the free parts. Discoaster ornatus has less rays (from 5 to 10 rays), more free parts of its rays (half of their length or more), more curved (to hook-shaped) and more deeply incised sutures between the rays on the superior face than in D. mohleri. Discoaster amrii shows similar construction to D. binodosus, except that the latter species has less arms (D. amrii has 13 to 16 arms while D. binodosus has 7 to 11 arms) than the former one and a pair of nodes at the end of each arm. The stratigraphic range of D. amrii is not overlaps with the stratigraphic range of the latter one at Gebel Atshan section, which make me not sure about their evolutionary relationship. Discoaster binodosus is considered to be evolved from D. ornatus by Romein (1979, p. 81) in the Middle of D. binodosus Zone (NP11). The first representative of Group II is D. multiradiatus.

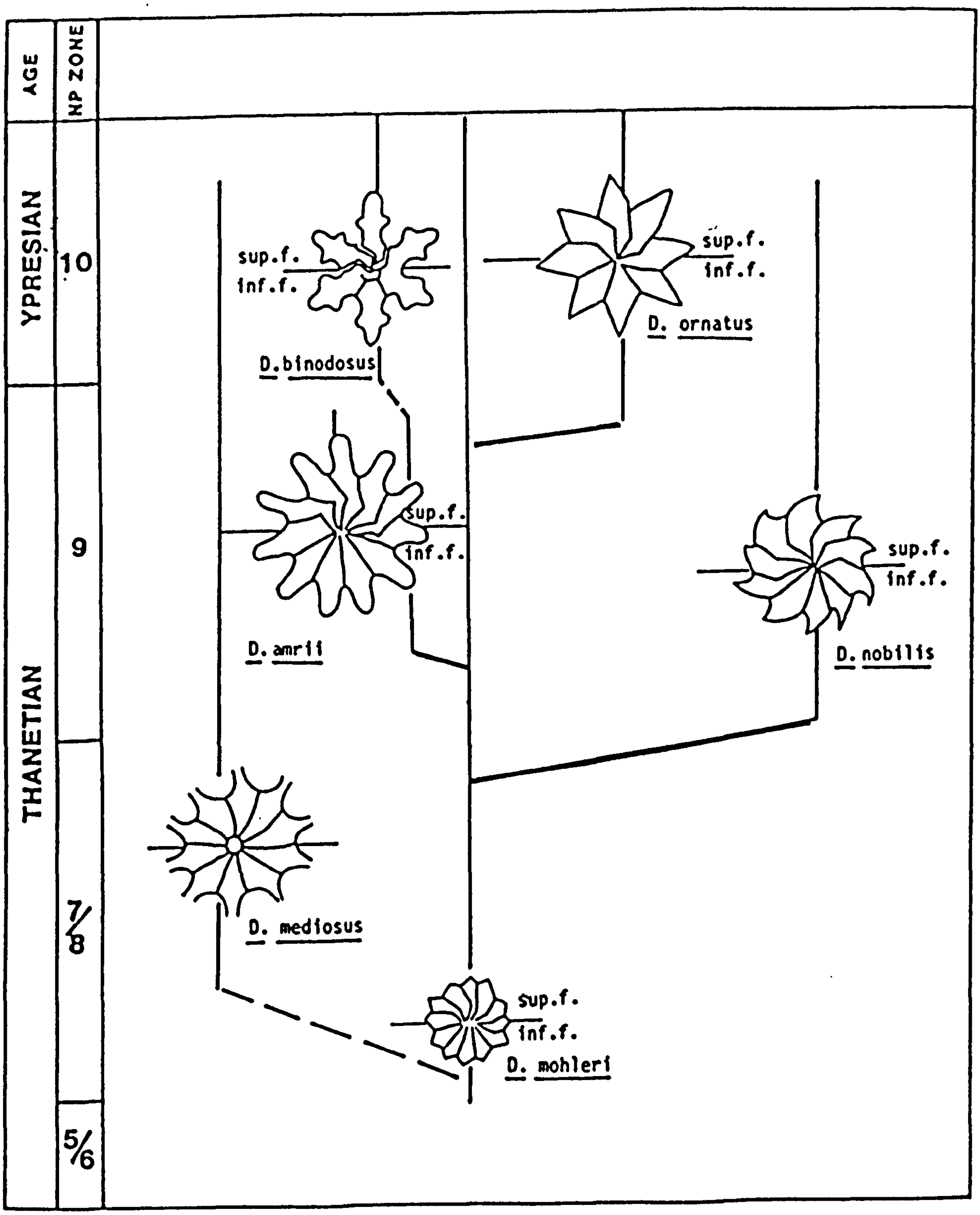


Fig.45-Evolutionary lineages in the genus Discoaster group I
(based partly upon Romein 1979,fig.42)

sup.f. = superior face
inf.f. = inferior face

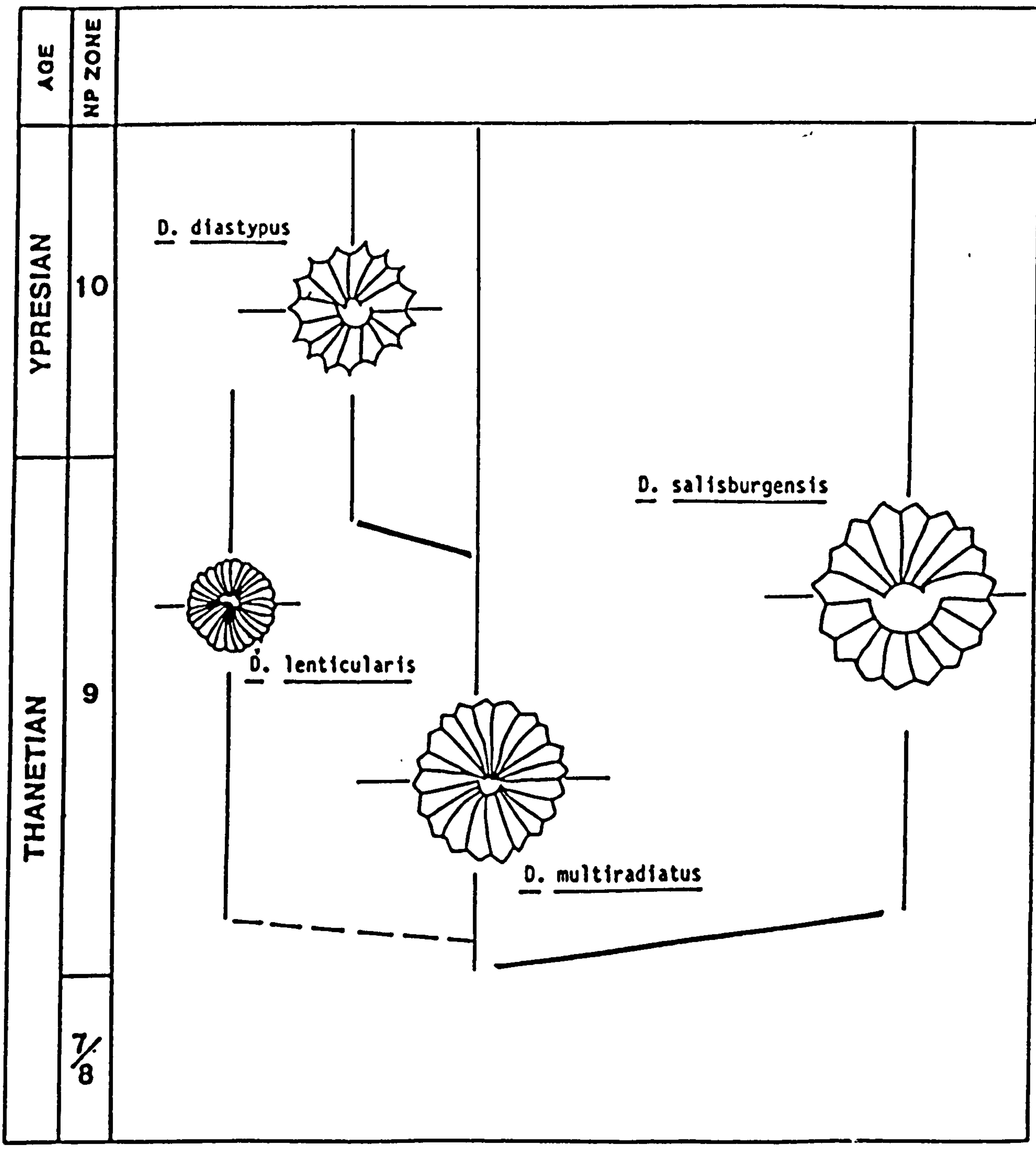


Fig.46-Evolutionary lineages in the genus Discoaster group II
(based partly upon Romein 1979,fig.44)

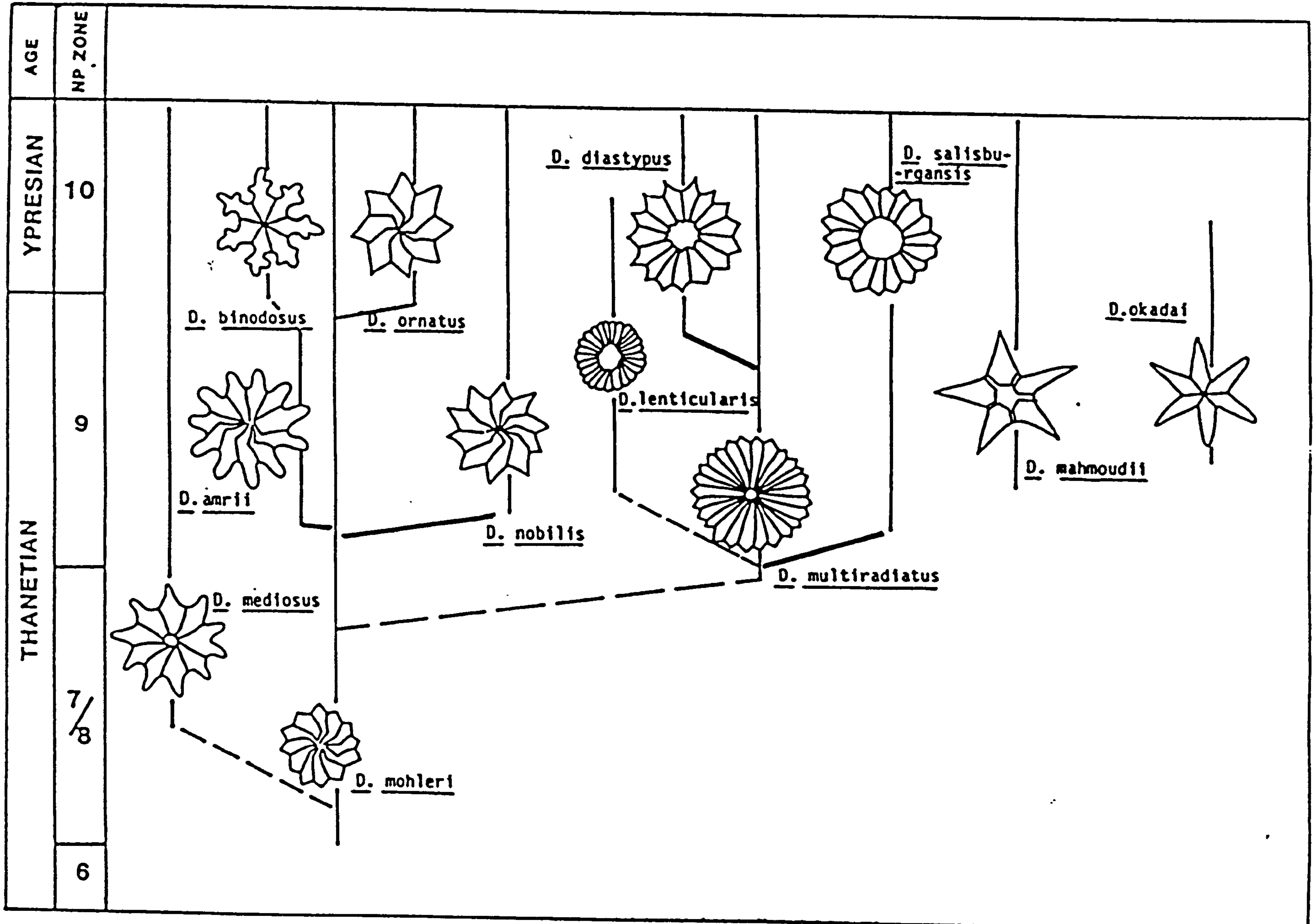


Fig.47 – Evolutionary lineages in the genus Discoaster

This species is believed to be evolved from D. mohleri by the increase of the number of rays (16 to 30 rays), displacement of the curved parts of the sutures on the superior face towards the centre, the presence of a stem in the centre and most of the disc becomes flat except the parts near the periphery (which are still biconvex). Romein (1979, p. 82) has considered Bomolithus megastypus the ancestor of D. multiradiatus. This transition in morphology is not observed here. Discoaster salisburgensis is evolved from D. multiradiatus by the increase of the diameter and the height of the central stem (being one third of the disc or more). This transition is thought to have happened in the base of the D. multiradiatus Zone (NP9). In the lineage from D. multiradiatus to D. diastypus the ends of the rays become more sharp and pointed, the number of rays become less (the number of rays of D. diastypus is 12 to 18), the development of two long stems (one on each side) one is broader than the other and the free ends of the stems become irregular with a hole inside them. Discoaster lenticularis is very rare and may be evolved from D. multiradiatus in the NP9 Zone by the reduction of the diameter to about 8 microns.

Discoaster okadai and D. mahmoudii are seen in the D. multiradiatus Zone (NP9) and the Tribrachiatus contortus Zone (NP10) in the studied sections. Both of them are star-shaped discoasters with few rays (compared to the asteroliths of this interval) which are similar to those star-shaped discoasters which occur later in time.

CHAPTER V

PALAEOECOLOGY

It is known from studies of Recent coccospheres that the number of fossilisable species is considerably lower than the number of living species. That is due to the dissolution during sinking which effects the different species differently. The diagenesis causes overgrowth of the part of the assemblage and dissolution removes other parts. Strictly speaking, thanatocoenoses give an imperfect, distorted image of the biocoenoses and make palaeoecologic studies extremely difficult. It is possible, however, to mention several palaeoenvironmental factors with reasonable confidence, if well preserved nannoplankton assemblages are available. The material examined in this project are varies in the state of its preservation. The Cretaceous assemblages are generally moderately preserved, while the Lower Tertiary ones are poorly to moderately (etched) preserved. Therefore, the state of preservation makes palaeoecological study difficult. The nannofossil assemblages of the Q. trifidum Zone at Gebel Tarbouli and Wadi Tarfa sections indicate a warm shallow marine condition. Quadrum trifidum, Q. sissinghii and Q. gartneri are rare to common in the zone at the above mentioned localities. These species are known to be abundant in deep water away from the continent also they are considered by Roth (1978, p. 740) to be warm water species. The absence (or very rare occurrence) of Lucianorhabdus cayeuxii and Phanulithus obscurus (high latitude marginal species) conform the warm conditions which were predominant during that time, Perch-Nielsen (1979a, p.258) suggested that Arkhangelskiella cymbiformis and Kamptnerius magnificus are more common in marginal than in an oceanic environment. These species are found to be common to abundant within this zone and later in the Maastrichtian. Braarudosphaera bigelowi (marginal species) is generally absent (or very rare) through the Cretaceous and the Early Tertiary in all the studied localities probably due to the same reasons mentioned for Lucianorhabdus cayeuxii. Thierstein (1976, p. 339) observed that species to be more abundant with increasing paleolatitude.

In the A. cymbiformis Zone and the L. quadratus Zone at Gabel Tarbouli, Wadi Mellaha, Gebel Duwi, Wadi Tarfa sections a higher diversity (the number of species increases towards the end of the L. quadratus Zone) than in Q. trifidum Zone is observed. The nannofossil assemblages of this interval indicate a more open marine (inner to outer shelf marine condition) stable warm environment. The rare to common occurrence of Lithraphidites praequadratus and L. quadratus (more abundant in cold water) reflect the warm conditions which were predominant in Egypt during that time. At the Upper Maastrichtian (N. frequens Zone) of Wadi Tarfa, Gebel Tarbouli, Wadi Mellaha, Gebel Duwi and Gebel Atshan sections Nephrolithus frequens (cold water, high latitude species) is more common than Micula murus and M. prinsii (tropical-subtropical warm water species). I think that the relative abundance of these two species is affected to a great extent by preservational factors. The latter species are delicate forms and easily broken or dissolved.

The nannofossil assemblages of the Early Palaeocene indicate a warm open marine environment. The nannofossil assemblages are dominated by abundant Thoracosphaera group (T. operculata and T. saxea) and Ericsonia group (E. cava, E. subpertusa, and E. eopelagica) forms, also Chiasmolithus and Cruciplacolithus groups are rare to common. The former two groups are considered to be more common in open sea and the species belonging to them are oceanic forms preferring a mainly warm climate. The latter two groups are mainly open sea, oceanic forms (Báldi-Beke 1984, p.188). In my opinion the palaeotemperature was very effective as Chiasmolithus and Cruciplacolithus species were not as common as the other groups. This is due to the preferance of the two latter groups to cold water environment (Bukry 1973). The absence of Braaudosphaera which is known to be a nearshore form (Edward and Perch-Nielsen 1975, p.477, Stradner and Steinmetz 1984, p.593) confirms the open marine and the warm conditions at that time. In the Late Palaeocene and the Early Eocene the nannofossil assemblages indicate a warm, more open marine condition than in the Early Palaeocene which is represented by the higher diversity (also the diversity is higher towards the end of the Palaeocene and the Early Eocene) and the domination of warm water nannofossil groups like Fasciculithus, Heliolithus, Bomolithus, and Discoaster Groups, also the absence (or rare occurrence) of nearshore species like _Zygrhablithus_ _bijugatus_, _Lophodolithus_ _nascens_ and _Discolithina_, _Transversoponitis_, _Pontosphaera_ groups (Báldi-Beke 1984, p.188).

CHAPTER V

SYSTEMATIC PALAEONTOLOGY

The problems encountered in the study of the calcareous nannofossils are:

1. When we find a fossil coccolith (isolated individual of a coccosphere), it is impossible (in most cases) to know the size, shape or the number of coccoliths in the coccosphere.

2. Coccolith polymorphism is a problem and complicates the systematics of this group. This is represented in three cases:

   A- One coccosphere possesses two different types of coccolith on one cell. When found as fossils, these would be given two different names.

   B- The presence of two phases in the life cycle, each phase producing coccospheres bearing coccoliths of an entirely different nature from those of the other phase. The non-motile phase of the life cycle produces heterococcoliths (formed of elements of varying sizes and shapes) and the motile stage of the life cycle produces holococcoliths (formed of elements of uniform size and shape). The coccoliths of the former phase are more common in the fossil record due to their robust construction and resistence to disintegration.

   C- Two names being given to the same species due to the effect of etching and overgrowth (Thierstein 1974, 1976).

3. A given coccolith has a different structural pattern in the distal and proximal views. In some cases, the distal and the proximal views of the same coccolith have been described by different authors as two different species or even genera. This was avoided here by tilting the (SEM) stub to try to recognise the two sides of each species during this work.

4. Some species were poorly defined and illustrated by authors and simple drawings may be included which were not good enough to represent the main structures and morphology which are a base in the systematic classification of calcareous nannofossils.

5. Some forms (INCERTAE SEDIS) do not have any morphological similarity or evolutionary relationship to other nannofossil groups and lack living representatives, e.g. discoasters.

In the present study the classification used for the calcareous nannofossils is a combination of the classification used by Hay and Mohler (1967) and Perch-Nielsen (1985), which is based on her earlier classification (1971a) after some modifications. In this selected classification the basis is not only the morphological features detected by the SEM and LM, but also the evolutionary relations between many groups especially those which appeared in the Early Tertiary.

In this chapter a new family, genus, and five new species are included. All species encountered in the investigated sections in the Maastrichtian and Early Tertiary from Egypt are discussed. A detailed description and/or short comments for many of the families, subfamilies, genera, and species is included. Selected synonymy is given for every species used in this study. Some discussion on the occurrence of selected species in Egypt and other places in the world is included.

Measurements for the dimensions of the species illustrated by the light microscope and the scanning electron microscope are given. In some cases, calculating the diameter or the length of the photographed specimens with the SEM was found to be less than the actual one, due to the oblique orientation of the specimen.

<u>Abbreviation used in this chapter:</u>

LM	= light microscope	Pc	= Phase contrast
CP	= Cross polarised light	D.S.	= distal side
P.S.	= Proximal side	S.V.	= Side view
SEM	= Scanning electron microscope		

Classification and Index of Calcareous Nannofossils recorded:

E. eopelagica (Bramlette and Riedel) Romein 1979 -p. 256

E. robusta (Bramlette and Sullivan 1961) Perch-Nielsen 1977 -p. 257

E. sp. A -p. 258

Chiasmolithus Hay, Mohler and Wade 1966 -p. 258

C. danicus (Brotzen 1959) Hay and Mohler 1967 -p. 259

C. consuetus (Bramlette and Sullivan 1961) Hay and Mohler 1967 -p. 261

C. californicus (Sullivan 1964) Hay and Mohler 1967 -p. 263

C. bidens (Bramlette and Sullivan 1961) Hay and Mohler 1967 -p. 264

C. eograndis Perch-Nielsen 1971 -p. 266

Family PRINSIACEAE Hay and Mohler 1967 -p. 267

Genus Prinsius Hay and Mohler 1967 -p. 267

P. dimorphosus (Perch-Nielsen 1969) Perch-Nielsen 1977 -p. 267

P. martinii (Perch-Nielsen 1969) Haq 1971 -p. 268

P. bisulcus (Stradner 1963) Hay and Mohler 1967 -p. 270

Toweius Hay and Mohler 1967 -p. 271

T. pertusus (Sullivan 1964) Romein 1979 -p. 272

T. eminens (Bramlet and Sullivan 1961) Gartner 1971 -p. 273

T. tovae Perch-Nielsen 1971 -p. 274

Family PONTOSPHAERACEAE Lemmermann 1908 -p. 322

Genus Pontosphaera Lohmann 1902 -p. 322

P. versa (Bramlette and Sullivan 1961) Romein 1979 -p. 322

P. exilis (Bramlette and Sullivan 1961) Romein 1979 -p. 323

2 - Division PYRROPHYTA Paschar 1914

Class DINOPHYCEAE Fritsch 1929

Order THORACOSPHAERALES Tangen et. al. 1982

Family THORACOSPHAERACEAE Schiller 1930 -p. 224

Genus Thoracosphaera Kamptner 1927 -p. 224

T. operculata Bramlette and Martini 1964 -p. 224

T. saxea Stradner 1961 -p. 226A

3 - INCERTAE SEDIS

3.1 Families INCERTAE SEDIS
(Groups based on morphological similarities and/or evolutionary relationships)

D. duwiensis n. sp. -p. 304
D. amrii n. sp. - p. 306
D. mohleri Bukry and Percival 1971 -p. 308
D. mediosus Bramlette and Sullivan 1961 -p. 310
D. nobilis Martini 1961 -p. 311
D. ornatus Stradner 1961 -p. 312
D. binodosus Martini 1958 -p. 313
D. multiradiatus Bramlette and Riedel 1954 -p. 315
D. lenticularis Bramlette and Sullivan 1961 -p. 316
D. diastypus Bramlette and Sullivan 1961 -p. 317
D. salisburgensis Stradner 1961 -p. 319
D. mahmoudii Perch-Nielsen 1981 -p. 321
D. okadai Bukry 1981 -p. 321

3.2 Genera INCERTAE SEDIS

Genus *Discolithina* Loeblich and Tappen 1963 -p. 151
D. spiralis (Pienaar 1968) Verbeek 1977 -p. 151
Marthasterites Deflandre 1959 -p. 238
M. inconspicuus Deflandre 1959 -p. 238
Ceratolithoides Bramlette and Martini 1964 -p. 239
C. aculeus (Stradner 1961) Prins and Sissingh 1977 -p. 239
C. kamptneri Bramlette and Martini 1964 -p. 239
Ellipsolithus Sullivan 1964 -p. 240
E. macellus (Bramlette and Sullivan 1961) Sullivan 1964 - p. 240
E. distichus (Bramlette and Sullivan 1961) Sullivan 1964 - p. 241
Scapholithus Deflandre 1954 -p. 242
S. apertus Hay and Mohler 1967 -p. 242

Family: ARKHANGELSKIELLACEAE Bukry 1969

Remarks:

The genera that have been included in this family are Arkhangelskiella Vekshina (1959), Broinsonia Bukry (1969), Gartnerago Bukry (1969), and Kamptnerius Deflandre (1959). The Family ARKHANGELSKIELLACEAE is characterised by a margin composed of three or four rim tiers (peripheral cycles of elements at different levels) and a central area which is divided into four quadrants by sutures or bars aligned with or slightly deviated from the major axis ofthe coccolith. the absence of stem and the presence of central sutures or bars distinguishes this family from the other families which have forms with three rim tiers.

Subfamily: ARKHANGELSKIELLOIDEAE Gartner 1968

Genus: Arkhangelskiella Vekshina 1959

Type species: Arkhangelskiella cymbiformis Vekshina 1959

Remarks:

This genus is characterised by a margin composed of four rim tiers (forms with three rim tiers not observed). In distal view, the central area is slightly convex and the distal rim tier is slightly concave. In side view, each rim tier is at a distinct level and the dimensions of the rim tiers decrease towards the proximal side; the two distal tiers are about the same size. In proximal view, the two proximal rim tiers are concave and the two distal ones are slightly convex.

Arkhangelskiella cymbiformis Vekshina

1959 Arkhangelskiella cymbiformis Vekshina, p.66, pl.2, figs.3a-b.

1964 Arkhangelskiella cymbiformis Vekshina, Bramlette and Martini, p.297, partim, pl.1, figs.3-8, non pl.1, fig.9.

1968 Arkhangelskiella cymbiformis Vekshina, Gartner, p.38, pl.1, figs.1-5, 6 (?), pl.4, figs.1-4, pl.6, figs.1a-c, pl.27, figs.2a-b.

1969 Arkhangelskiella cymbiformis Vekshina, Bukry, p.21, pl.1, figs.1-3.

1971 Arkhangelskiella cymbiformis Vekshina, Shafik and Stradner, p.80, pls.5-7.

1977 Arkhangelskiella specillata Vekshina, Verbeek, p.72, pl.2, figs. 1-2.

1980 Arkhangelskiella cymbiformis Vekshina, Hattner and Wise, p.57, pl.2, fig.3.

1983 Arkhangelskiella cymbiformis Vekshina, Doeven, p.47, pl.4, fig.4.

Description:

Large elliptical coccoliths with a broad margin and wide central area. The margin is formed of four rim tiers, each one is constructed of one cycle of regular radial elements. The central area is divided into four quadrants by two sutures aligned almost with the long and short axes of the ellipse. Each quadrant with five or less perforations situated along the sutures.

IN LM/PC, this species shows a bright margin and a less bright central area (with perforations) divided into eight equal wedges. In light microscope, cross-polarised light, the central area show the same eight wedges sharply divided and alternatively light and dark; each quadrant has two wedges with one bright and the other dark.

Figured material:

Plate 1, fig. 1. UCL-1877-28 Length = +8 μm (SEM)

Differentiation:

Arkhangelskiella specillata differs from A. cymbiformis in having a greater number of perforations (more than five pores), the pores in the later species are situated close and parallel to the long and the short sutures, while arranged in rows in the former species. The openings of the central area of A. specillata are smaller than those of A. cymbiformis. The margin of A. specillata is narrower than the margin of A. cymbiformis.

Arkhangelskiella cymbiformis differs from Gartnerago obliquum (Stradner) Reinhardt by:

(1) in the light microscope, cross-polarised light, the margin of the 8 alternatively dark and bright wedges of the central area are more distinct and more sharply defined in the former species.

(2) the pores of the central area in both species are close and parallel to the sutures, but the shape of the openings of A. cymbiformis is rounded, while rectangular or elongated in G. obliquum.

Remarks:

Arkhangelskiella specillata and A. cymbiformis are considered by many authors as one species in two different preservational states although the ranges given for these two species in the literature show considerable variation.

Gartner's illustrated specimen (1968, pl.1, fig.6) of Arkhangelskiella cymbiformis is difficult to identify as the central area is completely etched and the margin is overgrown. The two specimens illustrated by Verbeek (1977, pl.2, figs.1, 2) as A. specillata show a broad margin as in A. cymbiformis; also the central area is highly overgrown and does not show any pores.

Occurrence:

Arkhangelskiella cymbiformis has been well documented with a world-wide occurrence in Upper Cretaceous sediments. This species has been used as a zonal marker since it was found to be very common in Maastrichtian marine deposits. It is found in most of the Upper Cretaceous samples of my sections. The presence of very rare specimens of A. cymbiformis in Lower Tertiary sediments in Gebel Duwi, Gebel Atshan, Gebel Um El Ghanayem, Wadi Tarfa and Wadi Mellaha sections are due to reworking.

Arkhangelskiella specillata Vekshina

1959 Arkhangelskiella specillata Vekshina, p.67, pl.2, fig.5.

1968 Arkhangelskiella specillata Vekshina, Gartner, p.39, pl.8, figs.6-7, pl.11, figs.4a-c.

1969a Arkhangelskiella specillata Vekshina, Čepek and Hay, fig.4, no. 10.

1969 Arkhangelskiella specillata ethmopora Bukry, p.21, pl.1, figs.4-7.

1969 Broinsonia parca Bukry, partim, p.23, pl.3, figs.8-10, non. pl.3, figs.3-7.

non 1977 Arkhangelskiella specillata Vekshina, Verbeek, p.72, pl.2, figs.1-2.

1980 Arkhangelskiella specillata Vekshina, Hattner and Wise, p.57, pl.2, figs.4-9, pl.3, figs.1-2, pl.38, figs. 1-3.

1983 Arkhangelskiella specillata Vekshina, Doeven, p.48, pl.2, fig.4.

Description:

Elliptical coccoliths with large central area and four rim tiers. The number of pores in each quadrant of the central area is more than five and arranged in rows parallel to the short and long axes of the ellipse.

Figured material:

Plate 1, fig.2, UCL-1877-25.

Remarks:

Some specimens of A. specillata show random arrangement of the perforations of the central area which is due to overgrowth with secondary calcite which obscures some of these pores.

Bukry (1969) described A. specillata ethmopora as a subspecies on the basis of the number of processes meeting at the centre of each perforation to form a set of smaller openings. This delicate and fine construction always disappears due to etching or overgrowth and its detection is beyond LM resolution. Bukry's specimens (1969, pl. 3, figs. 8, 9, 10) which he identified as Broinsonia parca, have the number, the arrangement of the pores of the central area and the narrow rim are distinctive for A. specillata.

Occurrence:

Found commonly throughout the Upper Cretaceous in Egypt except Gebel Um El Ghanayem and Wadi Tarfa sections).

Genus: Broinsonia Bukry 1969

Type species: Broinsonia dentata Bukry 1969

Broinsonia parca (Stradner) Bukry

1963 Arkhangelskiella parca Stradner, p.10, pl.1, figs.3-3a.

1964 Arkhangelskiella parca Stradner, Bramlette and Martini, p.298, pl.1, figs.1-2.

1966 Arkhangelskiella cymbiformis Vekshina, Stover, partim, p.137, pl.1, figs.17a-b, non pl.1, fig.18, pl.8, fig.8.

1968 Arkhangelskiella parca Stradner, Gartner, p.38, pl.8, figs.4-5; pl.11, figs.2a-c.

1969 Broinsonia parca (Stradner) Bukry, p.23, partim, pl.3, figs.3-7, non pl.3, figs.8-10.

1972 Broinsonia parca (Stradner) Bukry, Perch-Nielsen, p.1007, pl.22, fig.5.

Figured material:

Plate 1, fig. 3. UCL-1865-4. Length: 11 µm (SEM)
Plate 12, fig.20. UCL 1856-19. Length: 11.7 µm (LM)

Remarks:

The central area of B. parca shows up to three perforations in each quadrant. As the number of pores decreases the central area becomes narrower and the margin becomes broader.

Occurrence:

The short vertical range of B. parca makes it stratigraphically an important species. This species ranges through the Campanian and the Lower Maastrichtian. Here the highest occurrence of this species is found in the lower part of the Arkhangelskiella cymbiformis Zone at Gebel Tarbouli, and Wadi Tarfa section.

Subfamily KAMPTNERIOIDEAE Bukry 1969

Remarks:

Bukry (1969) included two genera under this subfamily. These genera are Gartnerago Bukry (1969) and Kamptnerius Deflandre (1959). These two genera differ from Arkhangelskiella and Broinsonia in:

1) the degree of inclination of the rim tiers. In the former genera the rim tiers are more inclined towards the vertical (in side view) than the latter genera (Fig. 48).

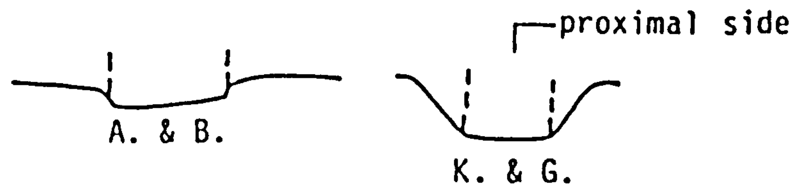


Fig.48 Schematic drawing to illustrate the differences between the genera Arkhangelskiella and Broinsonia ,and Kamptnerius and Gartnerago

2) in the LM/CP light,

a) the width of the bright margin in Arkhangelskiella and Broinsonia is more than in Gartnerago and Kamptnerius

b) the central area is more bright and distinct in Arkhangelskiella and Broinsonia

3) on the distal side, the central area of Arkhangelskiella and Broinsonia is less convex than the central area of the other two genera.

Genus: Gartnerago Bukry 1969

Type species: Arkhangelskiella concava Gartner 1968

Remarks:

Gartnerago differs from *Arkhangelskiella* and *Broinsonia* by:

1) the margin of the former genus consists of more rim tiers.

2) the elements of the rim tiers of the genus *Gartnerago* are more elongated, narrower and of greater number than those of *Arkhangelskiella* and *Broinsonia*

3) in proximal view, the elements of the inner rim tier of *Gartnerago* are strongly inclined.

4) in the genus *Gartnerago* the two sutures of the central area are parallel to one row of perforations at each side. These perforations are rectangular and elongated in shape compared to the perforations of the central area of the other two genera which are circular in shape.

Gartnerago obliquum (Stradner) Reinhardt

1963 *Arkhangelskiella obliqua* Stradner, p.10, pl.1, figs.2-2a.

1966 *Discolithus segmentatus* Stover, p.143, pl.3, figs.3-6, pl.8, fig.19.

1968 *Arkhangelskiella scapha* Gartner, p.39, pl.14, fig.1; pl.15, figs. 1a-d; pl.17, figs. 8a-d; pl.20, figs.1-3.

1968 *Arkhangelskiella costata* Gartner, p.37, pl.8, fig. 1-3, pl.11, figs. 1a-c; pl.28, fig.2.

1968 *Arkhangelskiella concava* Gartner, p.37, pl.14, figs. 2-3, pl.16; fig.5-7, pl.17, figs. 7a-d, pl.18, figs. 22-23, pl.19, fig.6, pl.21, figs. 7a-d, pl.22, figs. 13-15.

1969 Gartnerago costatum porolatum Bukry, p.24, pl.4, figs. 10-12.

1969 Gartnerago concavum (Gartner) Bukry, p.24, pl.4, figs. 2-6.

1969 Gartnerago costatum costatum (Gartner) Bukry, p.24, pl.4, figs.7-9.

1970b Gartnerago obliquum (Stradner) Reinhardt, p.66.

1974 Gartnerago segmentatum (Stover) Thierstein, p.640, pl.5, figs. 1-2; pl.6, figs. 1, 3-10, pl. 7, fig.6.

1981 Gartnerago costatum (Gartner) Bukry, Smith, p.47, pl.6, figs. 34-42, pl.7, figs.1-14.

Figured material

Plate 1, fig.4. UCL 1870-17 Length: 8 μm (SEM)
Plate 12, fig.18 UCL 2278-1 Length: 10.7 μm (LM)

Remarks:

Most of the specimens show a single row of perforations adjacent to and along either side of the long and the short sutures of the central area. Specimens which lack perforations are strongly overgrown.

In LM/PC, the central area is large, the margin is narrow and brighter than the central area. The perforations of the central area are visible.

In LM/CP, the central area is divided into eight, indistinct wedge-shaped segments. Each quadrant of the central area has one light and one dark wedge. The margin has at least 2 rim tiers.

Bukry (1969) separated Gartnerago costatum porolatum and Gartnerago costatum costatum on the basis of the shape, number of cross bars, and the orientation of the cross bars of the pores of the central area. His illustrated specimens show a great deal of etching and overgrowth.

Thierstein (1974) distinguished two species; G. obliquum with one row of perforations in the central area and G. segmentatum without any pores in the central area. The latter species is highly overgrown. He recognised these two species from generally poorly preserved material from the Central Indian Ocean and both have the same range and the abundance of each depends on the preservation of the assemblage in the samples.

Thierstein (1976) considered both species to be preservational conspecific morphotypes. In the study material forms which lack perforations in the central area are highly overgrown. Slightly overgrown specimen shows few pores and others are obscured.

Occurrence:

This species is recorded in nearly all the Maastrichtian samples examined.

Genus: Kamptnerius Deflandre 1959

type species: Kamptnerius magnificus Deflandre 1959

Remarks:

This genus is distinguished from the other genera of the family ARKHANGELSKIELLACEAE by its asymmetric inner distal rim tier.

In the LM/CP the genera of the family ARKHANGELSKIELLACEAE have a central area divided into eight distinct or indistinct wedge shaped alternating light and dark regions except Kamptnerius.

Kamptnerius magnificus Delflandre

1959 Kamptnerius magnificus Deflandre, partim, p.135, pl.1, fig.1, non pl.1., figs. 2-4.

1963 Kamptnerius punctatus Stradner, p.11, pl.2, figs.3-3a.

1964 Kamptnerius aff. K. magnificus Deflandre, Bramlette and Martini, pl. 2, figs. 1-2.

1968 Kamptnerius magnificus Deflandre, Gartner, partim, p.39, pl.2, fig.1; pl.3, figs. 7a-c, pl.6, figs. 10a-c; pl.10, fig.13; pl.15, figs. 10a-c; pl.16, fig.17, non pl.2, fig.2. pl.10, figs.11-12, pl.16, figs.18-19, pl.17, figs.11-12; pl.21, fig.12a-c, pl.12, figs. 9a-c pl.14, figs. 11-12.

1969 Kamptnerius percivalii Bukry, Partim, p. 25, pl.6, fig.3, non pl.6, figs.1-2.

1969 Kamptnerius punctatus Stradner, Bukry, p.26, pl.6, figs.4-5.

1970a Kamptnerius magnificus Deflandre, Hoffmann, p.859, pl.7, fig.2.

1971 Kamptnerius magnificus Deflandre, Shafik and Stradner, p.83, pls.8-10, pl.11,fig.1.

1971 Kamptnerius percivalii Bukry, Shafik and Stradner, p.83, pl.11, fig.2.

1977 Kamptnerius magnificus Deflandre, Verbeek, p.77, pl.3, figs. 4-5.

1978 Kamptnerius percivalli Bukry, Perch-Nielsen et al., partim, pl.1, fig.52, pl.2, figs.5-6, non pl.1, fig.53, pl.2, fig.3.

1980 Kamptnerius magnificus Deflandre, Hattner and Wise, p.63, partim, pl.19, figs.5-6, pl.20, figs.1,3-4 non pl.19, figs.4,7-9; pl.20, fig. 2.

1983 Kamptnerius magnificus Deflandre, Doeven, p.48, pl.4, figs. [illegible]-6.

Figured material:

Plate 1, fig.5. UCL 1925-11. Length: 10 μm (SEM)

Remarks:

Kamptnerius magnificus is a large elliptical form with an asymmetrical flange. This species consists of a wide central area and four narrow rim tiers. The inner distal cycle is narrower and closely appressed to the second distal rim tier. With good preservation, the central area shows numerous small pores. In etched forms, the asymmetrical flange is reduced and the pores of the central area are larger. In overgrown specimens, the central area is partly or strongly imperforated and the elements of the asymmetrical flange is thicker. In LM/CP, the margin is narrow, bright and elongated around the dark broad central area.

Differential diagnosis:

Kamptnerius magnificus differs from Gartnerago obliquum by:

1) in the proximal side, the rim tiers of the former species are narrower and more inclined towards the vertical position. In LM/CP K. magnificus has a narrower more bright margin.

2) in overgrown assemblages, proximal views, the central area of K. magnificus shows elongated ribs while in G. obliquum cubic or rhombic blocky elements are found.

3) in the LM/CP, the central area of K. magnificus does not divide into light and dark wedge-shaped regions like in the other species, but dark or faint bright central area is present instead.

4) in distal view, the central area of K. magnificus is strongly convex, while it is slightly convex or flat in G. obliquum.

5) the perforations in the central area of K. magnificus are circular while in G. obliquum they are square or rectangular.

6) Kamptnerius magnificus has an asymmetrical flange while G. obliquum has not.

Occurrence:

This species has a well-documented worldwide geographic occurrence within the Upper Cretaceous. It was also recorded by many authors (see the Synonymy list). This species is recorded here as a common species in the Upper Cretaceous strata of Egypt. It is also very rare in the Danian of Gebel Duwi and Wadi Tarfa sections.

Kamptnerius tabulatus Perch-Nielsen

1959 Kamptnerius magnificus Deflandre, partim, p.135, pl.1, figs.2-4, non pl.1, fig.1.

1963 Kamptnerius magnificus Deflandre, Stradner, p.13, pl.2, fig.2,2a.

1966 Kamptnerius magnificus Deflandre, Stover, p.144, pl.4, figs.28-30.

1968 Kamptnerius magnificus Deflandre, Gartner, partim, p.39, pl.2, fig.2; pl.10, figs.11-12, pl.12, figs. 9a-c, pl.14, figs. 11-12, pl.16, figs.18-19; pl.17, figs.11-12; pl.21, figs.12a-c, non pl.2, fig.1; pl.3, figs.7a-c, pl.6, figs.10a-c, pl.10, fig.13, pl.15, fig.10, pl.16, fig.17.

1968 Kamptnerius? tabulatus Perch-Nielsen, p.42, pl. 6, fig.4.
1969 Kamptnerius magnificus sculptus Bukry, p.25, pl.5, figs.10-12.

1969 Kamptnerius percivalii Bukry, partim, p.25, pl.6, figs.1-2, non pl.6, fig.3.

1974 Kamptnerius magnificus Deflandre, Thierstein, p.640, pl.8, figs.1-9, pl.9, figs.1-11.

1976 Kamptnerius magnificus Deflandre, Thierstein, p.351, pl.1, figs.1-2, pl.4, figs.38,39.

1977 Kamptnerius tabulatus Perch-Nielsen, Verbeek, p.78, pl.3, figs.6,7.

1978 Kamptnerius percivalli Bukry, Perch-Nielsen et al., partim, pl.1, fig.53, pl.2, fig.3, non, pl.1, fig.52, pl.2, figs.5-6.

1980 Kamptnerius magnificus Deflandre, Hattner and Wise, partim, p.63, pl.19, figs.4,7-9, pl.20, fig.2. non pl.19, figs. 5-6, pl.20, figs.1, 3-4.

Figured material:

Plate 1, fig. 6, UCL 2133-6 Length: 8 µm (SEM)

Remarks:

This species differs from K. magnificus by the presence of an asymmetrical margin while K. magnificus has an asymmetrical margin with a distinct sideward extending wing. Verbeek (1977) show that they are also different in their stratigraphic range, a K. tabulatus first appeared in the Middle Turonian and K. magnificus first appeared in the Lower Campanian.

Family: BISCUTACEAE Black 1971

Remarks:

This family includes genera which have coccoliths with elliptical and rounded outlines. These forms consist of two closely appressed shields, each shield constructes of radial, non-imbricate elements. In the LM/CP both shields are dark and the central area is bright.

Bidiscus Bukry 1969

Type species: Bidiscus cruciatus cruciatus Bukry 1969

Bidiscus ignotus (Górka) Hoffman

1957 Tremalithus ignotus Górka, p.248, pl.2, fig.9.

1970a Bidiscus ignotus (Górka) Hoffmann, p.862, pl.7, fig.1.

1971 Biscutum testudinarium Black, Shafik and Stradner, p.81, pl.3, figs.1-2, pl.4, fig.1.

non 1977 Bidiscus ignotus (Górka) Hoffmann, Verbeek, p.80, pl.3, fig.9.

1977 Bidiscus rotatorius Bukry, Verbeek, p.80, pl.3, fig.10.

Figured material:

Plate 1, fig.7, UCL 1919-31. Diameter:+2.6 μm (SEM)

Description:

This small circular species has two closely appressed shields. Each shield is constructed of one cycle of elements. The number of elements in both shields is the same and equal to 12 to 16 elements. The sutures between the elements in the distal shield are curved near the central opening and straight towards the periphery. The sutures between the elements in the proximal shield are straight. The elements which form the distal and the proximal shields are wide and gradually become thinner towards the central opening.

Remarks:

In this study, the forms of Bidiscus which have a small open central area and a distal shield consisting of one cycle of elements is considered B. ignotus.
I prefer to consider this species to belong to the genus Bidiscus rather than genus Discorhabdus Noël (1965). This is because the later genus was described from jurassic sediments and must show a well developed spine (Noël 1965, p.138), which was not observed in my Maastrichtian material. Therefore I used the Cretaceous generic name Bidiscus Bukry (1969) which was erected to include circular coccoliths of the Biscutaceae which lack spines.
Górka's specimen (1957) did not show any cycles of elements in the central area as a cycle, its presence, its number of elements, and the shape of the elements are used as a basis for describing many species and subspecies by Bukry (1969, p. 26, 27) and Hattner and Wise (1980, p. 57, 58). Forms with a cycle of four elements in the central area are not found in the Maastrichtian samples of the studied sections.
Verbeek (1977, p. 80), separated two forms belonging to Genus Bidiscus. Forms with cycle of four elements in the central area as B. ignotus and forms with very small open central area and a broad marginal cycle of about 13 elements as B. rotatorius Bukry 1969. His SEM-photographs (pl. 3, figs. 9 and 10) are similar and do not illustrate these differences.

Occurrence:

This species is consistently present in the Upper Cretaceous of Gebel Duwi, Gebel Atshan, Wadi Tarfa and Gebel Tarbouli.

Genus *Biscutum* Black 1959

Type species: *Biscutum testudinarium* Black, in Black and Barnes 1959

Biscutum constans (Górka) Black

1957 *Discolithus constans* Górka, p.279, pl.4, fig.7.

1959 *Biscutum testudinarium* Black, in Black and Barnes, p.325, pl.10, fig.1.

1967 *Biscutum constans* (Górka) Black, p.139.

1968 *Biscutum blacki* Gartner, p.18, pl.1, fig.7; pl.6, figs.2a-c, pl.8, figs.8-10, pl.11, figs.8a-c, pl.15, figs.2a-c, pl.16, fig.8.

1969 *Biscutum asymmetricum* Perch-Nielsen, Bukry, p.27, pl.7, figs.10, 11.

1971 *Biscutum constans* (Górka) Black, Shafik and Stradner, p.81, pl.2, figs.1-4.

1981 *Biscutum constans* (Górka) Black, Hattner and Wise, p.58, pl.4, fig.3.

Description:

Biscutum constans is an elliptical coccolith constructed of two shields. Each shield is formed by one cycle of wedge-shaped non imbricating elements. The proximal shield is smaller than the distal one. In each shield the elements of the two far ends are broader than the other elements.

In distal view, the sutures between the elements are straight but they become crooked near the central area. In proximal view, the sutures between the elements of the proximal shield are straight and the central area is surrounded by a very small opening. A cycle of elements in the central area is present in distal view. The coccospheres of this species are elliptical elongated or circular.

Remarks:

In LM/PC, the two shields of Biscutum constans appear dark and the central area is bright with distinctive dark lines at the two far ends. In cross-polarised light, the central area is bright and the two shields are dark.

Biscutum constans differs from Watznaueria barnesae (Black) Perch-Nielsen by:

1) in distal view, the distal cycle of the distal shield of the former species is formed of non imbricating elements, while they are imbricating in the marginal cycle of the distal shield of the latter species.

2) the sutures between the elements of the distal shield of B. constans are radial, while they are inclined in the other species.

3) the number of elements of B. constans is less than in W. barnesae.

4) Biscutum constans is smaller than W. barnesae.

5) in light microscope, phase contrast, a dark line aligned with the major axes of the ellipse which is present, is distinctive for B. constans, this is absent in W. barnesae.

6) in cross-polarised light, B. constans has a bright central area with x-shaped dark lines and dark margin, while W. barnesae has a bright margin and bright central area which is bisected by x-shape dark lines.

Occurrence:

Biscutum constans is a common species worldwide within the Cretaceous sediments. It is recorded in the Upper Cretaceous sediments of the study sections.

Family: ELLIPSAGELLOSPHAERACAEA Noël 1965

Remarks:

This family includes rounded and elliptical coccoliths with margins constructed of two shields. The distal shield is constructed of a cycle of imbricating elements, an inner cycle may be present. The proximal shield is formed of radially arranged elements which is slightly imbricating. The central area is open or filled with tiny elements.

Genus: Markalius Bramlette and Martini 1964

Type species: Cyclococcoliths leptoporus Murray and Blackman, var. inversus Deflandre in Deflandre and Fert 1954

Remarks:

This genus is distinguished by its circular outline, two closely appressed shields each one composed of one cycle of elements and a central area forming a depression in distal view.

Markalius astroporus (Stradner) Hay and Mohler

1954 Cyclococcolithus leptoporus Murray and Blackman var. inversus Deflandre, in Deflandre and Fert, partim., p.150, pl.9, figs. 4-5, non pl. 9, figs. 6-7.

1963 Cyclococcolithus astroporus Stradner, in Gohrbandt, p.75, pl.9, figs.5-7, text-fig. 3 (2a-b).

1964 Markalius inversus (Deflandre) Bramlette and Martini, partim, p.302, pl.2, figs.4-9, non pl.7, figs.2a-b.

1967 Markalius astroporus (Stradner) Hay and Mohler, p.1528, pl.196, figs.32-35, pl.198, figs.2-6.

1971 Markalius inversus (Deflandre) Bramlette and Martini, Shafik and Stradner, p.84, pl.3, figs.3-4.

1975 Markalius inversus (Deflandre) Bramlette and Martini, Grun and Allemann, p.199, text-figs.33a-c, pl. VIII, fig.6.

1977 Markalius inversus (Deflandre) Bramlette and Martini, Verbeek, p.84.

1979 Markalius astroporus (Stradner) Hay and Mohler, Romein, p.98, pl.1, fig.7.

Remarks:

The photographed specimens were referred to Markalius inversus (Deflandre) by Bramlette and Martini (1964, pl. 7, Figs. 2a, 2b), they represent specimens belonging to the genus Ericsonia Black (1964) as the proximal views show three cycles of imbricating elements. The other photographed specimens by the above mentioned authors (pl. 2, figs. 4-9), represent Markalius inversus (=M. astroporus).

Occurrence:

This species was recorded by many authors in different places in the world. Bramlette and Martini (1964, p. 292, 302) have recorded Markalius inversus (=M. astroporus) as a common species in the type Danian of Denmark. They have also recorded it from sediments of equivalent age from southwestern France and Tunisia. They have also found rare specimens in the Maastrichtian of Denmark and Alabama. In 1967 Hay and Mohler, p.1510 used this species to define the lower most zone (Markalius astroporus Zone) of the Palaeocene at Pont Labau South of France. Also they have observed this species randomly throughout the whole Palaeocene, (they have considered it as possibly reworked). Verbeek (1977, p. 25) has recorded this species in the Maastrichtian and Early Danian of the El Kef section (Tunisia). Romein (1979, p. 25, 34, 98) has found this species in the Caravaca and Aspe sections in South East Spain with a stratigraphic range from the Biantholithus sparsus Zone to the Discoaster mohleri Zone, in Nahal Avdat section in Israel with range from the B. sparsus Zone to the Cruciplacolithus tenuis Zone (=NP2 and NP3) and in Scandinavia from the B. sparsus Zone to the Ellipsolithus macellus Zone NP4 (=NP4a and NP4b, this work). In this work, this species is recorded from Gebel Duwi (NP3-NP9), Gebel Atshan (NP3-NP10), Wadi Tarfa (NP5/6-NP9), Gebel Um El Ghanayem (NP7/8-NP9), Gebel Tarbouli (N. frequenes Zone and NP10) and Wadi Mellaha (N. Frequens Zone-NP10).

Genus: Watznaueria Reinhardt 1964

Type species: Watznaueria angustoralis Reinhardt 1964

Watznaueria barnesae (Black) Perch-Nielsen

1959 Tremalithus barnesae Black, in Black and Barnes, p.325, pl.9, figs.1,2.

1968 Coccolithus barnesae (Black) Gartner, p.17, pl.1, fig.12; pl.4, figs.6-7, pl.8, figs.18-22, pl.11, figs.11a-c, pl.14, figs.4-5, pl.15, figs.8a-d, pl.16, figs.15-16. pl.20, figs. 12-13; pl.22, figs. 16-17, pl. 24, figs.8a-d, pl. 25, figs.1-2.

1968 Watznaueria barnesae (Black) Perch-Nielsen, p.69, pl.22, figs.1-7; pl.23, figs.1,4-5,16.

1971 Watznaueria barnesae (Black) Perch-Nielsen, Shafik and Stradner, p.90, pl.1, figs.1-5, pl.4, fig.2.

1973 Coccolithus barnesae (Black), El-Dawoody and Barakat, pl.10, figs.2a-b.

1978 Watznaueria barnesae (Black) Perch-Nielsen, Perch-Nielsen et al., pl.1, figs. 33,34, pl.6, figs.9,12.

Remarks:

Very abundant species in Upper Cretaceous sediments. It is very resistant to dissolution and overgrowth and is distinguished by an elongate narrow slit-like opening in the central area.

Verbeek (1977) illustrated Watznaueria barnesae (pl. 4, fig. 6) which is a coccosphere for W. biporta as the central opening seems to be two openings effected by dissolution.

Occurrence:

Watznaueria barnesae has a well documented worldwide occurrence throughout the Upper Cretaceous. It dominated the nannofossil assemblages of most of the Maastrichtian samples studied during this research. Also it is recorded in the Chiasmolithus danicus Zone (NP3) from Gebel Duwi and Gebel Atshan, and in the E. macellus Zone from Gebel Um El Ghanayem which is considered to be reworked.

Watznaueria biporta Bukry

1969 Watznaueria biporta Bukry, p.32, pl.10, figs.8-10.

1975 Watznaueria biporta Bukry, Grün and Allemann, p.164, text-figs.9a-c, pl.2, figs.11-12.

1977 Watznaueria biporta Bukry, Verbeek, p.85, pl.4, fig.5.

1977 Watznaueria barnesae (Black) Perch-Nielsen, Verbeek, p.85, pl.4, fig.6.

1978 Watznaueria biporta Bukry, Perch-Nielsen et al., pl.6, fig.6.

Remarks:

Watznaueria biporta is distinguished from W. barnesae by :

1) the presence of two perforations in the central area aligned with the long axis of the ellipse while in the latter species an elongated narrow slit-like opening is present in the central area.

2) in distal view a cycle of diagonal elements in the central area around the two openings is present in the former species but absent in the latter one.

Bukry (1969) described little processes in the perforations of the central area. These processes seem to be a preservational feature, as they are not observed through the investigation of this species through this project.

Verbeek's illustrated specimens (1977, pl. 4, fig. 6) of W. barnesae are considered here W. biporta for these reasons:

1) the presence of a cycle of diagonal elements around the perforations of the central area (distal side)

2) the central area shows two openings effected by dissolution

Watznaueria biporta is rare in the Upper Cretaceous sediments (the studied sections in Egypt). This species is not as common as W. barnesae. The preservation state may be responsible for this as in poor preservation, the central area is obscured by overgrowth or etched due to dissolution and it becomes very difficult to separate the two species in the LM or the SEM.

Family: AHMUELLERELLACEAE Reinhardt 1965
Genus: Ahmuellerella Reinhardt 1964
Type species: Ahmuellerella limbitenuis Reinhardt 1964

Remarks:

Genus Ahmuellerella includes species with an elliptical margin consisting of a broad imbricating cycle of elements and one or two narrow cycles of elements. The margin is attached to a conical central structure composed of eight bars ended by a long stem.
Gartner (1968) described a genus "Actinozygus" with the type species Tremalithus regularis Górka 1957. This species is considered to be Ahmuellerella regularis (Górka) therefore genus Actinozygus is a junior synonymus for Ahmullerella.

Ahmuellerella octoradiata (Górka) Reinhardt

1957 Discolithus octoradiatus Górka, p.259, pl.4, fig.10.

1964 Ahmuellerella limbitenuis Reinhardt, p.751, pl.1, fig.6; pl.2, fig.6; text-fig.1.

1966a Ahmuellerella octoradiata (Górka) Reinhardt, p.24, pl.22, figs.3-4.

1968 Eiffellithus octoradiatus (Górka) Gartner, p.25, pl.2, figs.17-21, pl.3, figs.11a-c; pl.5, fig.20; pl.12, figs.10a-c.

1969 Vagalapilla octoradiata (Górka) Bukry, p.58, pl.33, figs.5-7.

1971 Ahmuellerella octoradiata (Górka) Reinhardt, Shafik and Stradner, p.80, pl.23, figs.1-4.

1978 Ahmuellerella octoradiata (Górka) Reinhardt, Perch-Nielsen et al., pl.1, figs.13-14.

1981 Ahmuellerella octoradiata (Górka) Reinhardt, Smith, p.27, pl.1, figs.1-15.

Figured material:

Plate 1, fig.8, UCL-1934-5 Length: 7 μm (SEM)

Remarks:

In poor preservation, this species is more distinctive in the LM/CP, than in LM/PC particularly in an overgrown assemblage as the divergent pairs of bars seem like one bar. In cross-polarised light, when the species is oriented with the major axes parallel to either nicols the four pairs of bars are bright and each pair bisected by a thin dark line.

Gartner (1968, p. 24, 25) put this species under the genus Eiffellithus Reinhardt (1965) as the cross bars of the central area are not aligned perfectly with the major axes. In my material, some forms have four pairs, of crossbar aligned or slightly deviated from the main axis. Also the construction of the margin and the bars of the central area (4 pairs not two cross bars as in the type species of Eiffellithus) differs, from those of the genus Eiffellithus.

Occurrence:

This species is well documented to have a worldwide occurrence in the Upper Cretaceous. Ahmuellerella octoradiata is found in most of Maastrichtian samples of all the studied sections (except Gebel Um El Ghanayem and Wadi Tarfa sections).

Ahmuellerella regularis (Górka) Verbeek

1957 Tremalithus regularis Górka, p.246, pl.2, fig.4.

1968 Actinozygus regularis (Górka) Gartner, p.23, pl.3, figs.12a-c, pl.5, figs.17-18, pl.6, figs. 17-18, pl.12, fig.11a-c.

1968 Actinozygus splendens (Deflandre) Gartner, partim, p.25, pl.10, fig.1, non pl.5, figs.15-16, pl.7, figs.1-2, pl.11, figs.15a-c

1969 Parhabdolithus regularis (Górka) Bukry, p.53, pl.30, figs.8-10.

1969 Parhabdolithus granulatus Stover, Bukry, p.53, pl.30, figs. 4-6,7?

1971 Rhagodiscus plebeius Perch-Nielsen, Shafik and Stradner, p.88, pl.26, figs.2-4, pl.27, figs.1-2,4.

1971 Reinhardtites mirabilis Perch-Nielsen, Shafik and Stradner, p.88, pl.24 and pl.25.

1977 Ahmuellerella regularis (Górka) Verbeek, p.86, pl.4, fig.9.

1978 Reinhardtites mirabilis Perch-Nielsen, Perch-Nielsen et al., pl.1, figs. 10-11, pl.4, figs. 3,7,10.

1980 Rhagodiscus splendens (Deflandre) Verbeek, Hattner and Wise, p.67, partim, pl.30, figs.5,7, non pl.30, figs.3, 4,6,8.

Figured material:

Plate 1, fig.9 UCL-2130-8 Length: 5 μm (SEM)
fig.10 UCL-2152-2 Length: 7 μm (SEM)
Fig.11 UCL-2152-1 Length: 7 μm (SEM)

Remarks:

This species differs from Ahmuellerella octoradiata (Górka) Reinhardt by:

1) having 8 regularly spaced bars, while A. octoradiata has 4 pairs of bars parallel or slightly deviated from the main axes of the ellipse of the basal disc.

2) side view (the stem upwards), A. regularis shows a flat or slightly convex rim and the bars of the central area are slightly convex towards the rim but strongly convex or nearly vertical close to the stem forming a cone-like shape. Ahmuellerella octoradiata has a flat rim and the bars of the central area are gradually convex towards the stem forming a more or less pyramid like shape.

3) distal view, the rim of A. regularis is broader than that of A. octoradiata.

In well preserved assemblages, each bar of the central area of A. regularis from the distal side is formed of two rows of elements which are slightly bifurcated close to the rim. In highly overgrown specimens the bars of the central area are obscured as secondary calcite fills the open areas between them. This makes some authors consider it as a different species (See Synonymy list).

Occurrence:

This species is found throughout the Maastrichtian strata of the studied sections except Gebel Um El Ghanayem.

Genus: *Vekshinella* Loeblich and Tappan, emend. Gartner 1968

type species: *Vekshinella* *acutiferrus* (Vekshina) Loeblich and Tappan 1963 (=*Ephippium* *acutiferrus* Vekshina 1959).

Remarks:

These are small elliptical forms with a margin of two cycles of elements and a central cross bars parallel to the axes of the elliptical disc with or without a central spine. Three generic names are used for this group.

1) Genus *Staurolithites* Caratini (1963) which includes forms with a rim and any sort of cross bars in the central area. This genus is emended by Black (1971) to restrict this genus to forms with cross bars parallel to the major axes of the ellipse.

2) Genus *Vekshinella* Loeblich and Tappan (1963). The genus *Ephippium* was described by Vekshina (1959). The type species *E. acutiferrus* Vekshina, was described as an elliptical rim with axial cross bars and one short spine on one side and a long one on the other side. Loeblich and Tappan (1963) changed the name of the above mentioned genus to *Vekshinella* because they found that name to be preoccupied. Gartner (1968) emended the genus *Vekshinella* to include elliptical forms with an elliptical basal disc which is constructed of a single cycle of imbricate elements, cross bars parallel to the main axes and a spine which may presnt or may not be present.

3) Genus *Vagalapilla* Bukry (1969). Bukry restricted this genus to forms with a margin constructed of two cycles of elements (one composed of imbricating elements in distal view and one secondary cycle of elements occuring at the central area margin in proximal view), axial alignment of the cross bars and stem or spine which extends "only" from the distal surface.

Verbeek (1977, p. 95) mentioned that he observed that in Gartner's paper (1968) the species belonging to the genus _Vekshinella_ has two cycles visible. In that respect he considered genus _Vagalapilla_ as a junior synonym.

Vekshinella _ara_ Gartner

1968 _Vekshinella_ _ara_ Gartner, p.29, pl.2, fig.24, pl.3, figs.15a-c.

1969 _Vagalapilla_ _aachena_ Bukry, p.55, pl.31, figs.6-9.

Description:

This species has an elliptical shape and is composed of a distal cycle of 35 to 50 strongly imbricating elements and a narrower proximal cycle. The central area is occupied by cross bars aligned with the major axes of the basal disc. The width of the cross bars is variable. Each one of the central cross bars is composed of elongated thin elements and a triangular element is located at each side of the bar (close to the margin). A long spine is present at the centre of the cross bars.

Figured material:

Plate 1, fig.12 UCL-1919-10 Length: 4.5 μm (SEM)
fig.13 UCL-1919-12 Length: 6.6 μm (SEM)

Remarks:

The serrate margin of Gartner's specimen (1968, pl. 2, Figure 24) is not a primary feature as the specimen was affected by overgrowth. The other specimen Plate 3, figure 15 does show a regular outline (not serrate).

Vekshinella compacta (Bukry) n. comb.

1969 Vagalapilla compacta compacta Bukry, p.56, pl.31, figs.10-11.

1969 Vagalapilla compacta integra Bukry, p.56, pl.31, fig.12.

Figured material:

Plate 1, fig.14. UCL-2130-14. Length 4 µm (SEM)
fig.15. UCL-1919-7. Length 4 µm (SEM)

Description:

This elliptical elongate species has a margin made up of distal broad cycle of strongly imbricating elements and a proximal narrow cycle of slightly imbricating delect elements. The cross bars of the central area are aligned with the major axes of the ellipse or are slightly deviated. Their width is highly variable. Each bar is formed of 2 rows of one or more large irregular elements divide by median suture. Rare forms have the long bar slightly offset.

Remarks:

This species differs from Vekshinella ara by:

1) Vekshinella compacta in plan view is elliptical, elongate and serrate in outline, while V. ara has an elliptical shape without a serrate outline.

2) the outline of the cross bars of V. compacta is irregular while it is regular in the other species.

3) the number of elements forming the cross bars of V. compacta is more than that of V. ara.

4. the rim of _V. compacta_ is higher than that of _V. ara._

5) no spine or stem is present on the distal side of _V. compacta_ while _V. ara_ has a long spine.

The difference between _V. compacta compacta_ and _V. compacta integra_ by Bukry (1969, p. 56) were not detected in this work.

Occurrence:

This species was described by Bukry (1969) from the Lower Austin Chalk (of Early Santonian age) of farm road 1382 (the type locality) South Dallas Country, Texas. _Vekshinella compacta_ is rare in the Maastrichtian of Gebel Tarbouli, Gebel Duwi, and Wadi Mellaha section.

Vekshinella dorfii (Bukry) n. comb.

1969 _Vagelapilla dorfii_ Bukry, p.57, pl.32, figs.7,8.

Description:

This species has a narrow sub-elliptical to subcircular outline. The margin of _V. dorfii_ is composed of strongly imbricating elements forming the distal cycle and a proximal cycle made up of slightly imbricating delect elements. The central area is large and bisected by cross bars parallel to the major axis of the ellipse. A distinctive hollow stem is presnt at the intersection of the cross bars.

Figured material:

Plate 2, Figure 1. UCL-2135-30 Length: 4 µm (SEM)

Remarks:

This species is distinguished from the other species of the genus Vekshinella by its broad open central area with comparatively narrow central cross bars, and the hollow stem.

Occurrence:

This species is rare in a few Maastrichtian samples at Wadi Esh Mellaha section.

Vekshinella elliptica Gartner

1968 Vekshinella elliptica Gartner, p.30, pl.17, figs.5a-d, pl.25, figs.26,27, pl.26, figs.7a-d.

1969 Vagalapilla elliptica (Gartner) Bukry, p.57, pl.32, figs.9-12.

1982 Staurolithites ellipticus (Garnter) Black, Crux, pl.5.3, figs.13-15, pl.5-9, fig. 20.

Description:

This species is elliptical with a smooth or slightly serrate margin. The margin is composed of a distal cycle which is formed of strongly imbricating elements. The sutures between the elements, of the distal cycle on the distal side, are inclined towards the central area but it deviates to become perpendicular on the margin outwards. The proximal cycle is narrow and constructed of slightly imbricating elements. The central area is spanned by two broad cross bars aligned with the short and long axis of the ellipse. Each bar is composed of numerous small elements. Some forms show bars with another layer of broader, larger and fewer elements over the other one.

Figured material:

Plate 2, fig.2. UCL-2131-1 Length: 4 μm (SEM)

Remarks:

This species is distinguished by the shape of its cross bar, which is broader toward the inter section and narrower towards the margin. *Stauralithites ellipticus* (Gartner) Black is invalid ICBN Art. 33.2. (In the INA-Newsletter, Vol.3, 1981, p. 77).

Occurrence:

This species is recorded in few areas in the world. Gartner (1968, p. 13,15,30) has reported this species from the Eagle Ford Shale (Upper Cenomanian-Turonian) and the Taylor Marl (Campanian) of the Northwestern Gulf Coast. Crux (1982, p. 107, 116) has reported *staurolithites ellipticus* (=*V. elliptica*) from a Campanian marine section along the coast of north Norfolk in southeastern England. This species is found in few Maastrichtian samples in Wadi Tarfa, Gebel Tarbouli, and Wadi Mellaha Sections.

Vekshinella crux (Deflandre and Fert) Risatti

1954 *Discolithus crux* Deflandre and Fert, p.143, pl.14, fig.4, text-fig.55.

1961 *Zygolithus crux* (Deflandre and Fert) Bramlette and Sullivan, p.149, pl.6, figs.8-10.

1968 *Vekshinella imbricata* Gartner, p.30, partim, pl.9, fig.17, pl.13, figs.8,9, non pl.9, fig.16.

1969 *Vagalapilla imbricata imbricata* (Gartner) Bukry, p.57, pl.33, figs.1,2.

1973 Vekshinella crux (Deflandre and Fert) Risatti, p.19, pl.7, figs.24-25.

Description:

Vekshinella crux has a thin and high elliptical margin. The distal cycle is composed of strongly imbricating elements. The central area is occupied by cross bars aligned with the long and short axis of the coccolith. Each bar is made up of many small elongate elements. The ends of each bar close to the margin is slightly wider than the rest of the bar (it is not clear if there is a triangular elements around the ends of the bars or not).

Figured material:

Plate 2, fig.3, UCL 2131-27. Length: +3 μm (SEM)

Remarks:

Vekshinella crux differs from V. dorfii by:

1) the outline of the former species is elliptical to elliptical elongate while it is subelliptical to subcircular in the latter species.

2) the cross bars of V. crux are more robust and shorter than those of V. dorfii (compared to the width of the margin of each species).

3) the open central area of V. crux is smaller than the central area of V. dorfii.

Occurrence:

This species is well documented through the Cretaceous and has been reported by many authors in different areas in the world. Also it was reported by Hamilton (1982, p. 28, 38) in Oxfordian strata in Millbrook, Bedfordshire North of London. This species is found in the Maastrichtian of the studied sections (Gebel Atshan, Gebel Duwi and Wadi Mellaha).

Vekshinella dibrachiata Gartner

1968 Vekshinella dibrachiata Gartner, p.30, pl.5, figs.23, 24, pl.7, figs.8a-c, pl.9, fig.15; pl.19, figs.8a-d, pl.22, fig.8.

Figured material:

Plate 2, fig.4, UCL-2133-22 Length: 6 Um (SEM)

Remarks:

This species might be a poorly preserved V. compacta as the specimens which are found in this study and the specimens which were illustrated by Gartner (1968) are badly preserved.

Occurrence:

Rare species in the Maastrichtian strata of Wadi Mellaha Section.

Family: CHIASTOZYGACEAE Rood, Hay and Barnard 1973

Genus: Chiastozygus Gartner 1968

Type species: Zygodiscus? amphipons Bramlette and Martini 1964

Remarks:

The genus Chiastozygus includes species with open central area spanned by X-shaped cross bars (or diagonal cross bars) and rims with a broad cycle constructed of strongly imbricating elements. The margin might have another one or two narrow cycles.

Chiastozygus amphipons (Bramlette and Martini) Gartner

1964 Zygodiscus? amphipons Bramlette and Martini, p.302, pl.4, figs.9,10.

1968 Chiastozygus amphipons (Bramlette and Martini) Gartner, p.26, partim, pl.8, figs.11-14, pl.11, figs.9a-c, pl.22, fig.10. non pl.22, fig.11.

1968 Chiastozygus plicatus Gartner, p.27, pl.16, figs.10-11, pl.17, fig.9a-c, pl.19, figs.9a-d, pl.20, fig.6, pl.21, figs.9a-d, pl.22, fig.12.

?1969 Chiastozygus amphipons (Bramlette and Martini) Gartner, Bukry, p.49, pl.26, figs.8,9.

1971 Zygolithus litterarius (Górka) Reinhardt and Gorka, Shafik and Stradner, p.92, pl.41, figs.1-4.

1977 Chiastozygus litterarius (Górka) Manivit, Verbeek, p.87, pl.5, figs.2,3.

1977 Chiastozygus amphipons (Bramlette and Martini) Gartner, Verbeek, p.87, pl.5, fig.1.

1978 Chiastozygus litterarius (Górka) Manivit, Perch-Nielsen et al., pl.1, figs.9, 10, pl.5, figs. 13,17.

1978 Chiastozygus litterarius (Górka) Manivit, Perch-Nielsen et al., pl.1, figs.9-10, pl.5, figs. 13,17.

1981 Chiastozygus plicatus Gartner, Smith, p.32, pl.2, figs.1-12.

Description:

Chiastozygus amphipons is recognised by the broad, elliptical central area which is spanned by x-shaped cross bars which form an acute angle with the short axis of the ellipse. These cross bars divide the open central area into two small circular openings along the transverse axis and two larger circular to subcircular openings along the long axis. Investigation of many specimens in the SEM show that each bar is formed of two large elements separated by a distinctive suture parallel to the long axis of the bar. Over each bar, on distal side, elongated small calcite elements form the stem at the intersection of the cross bars.

Remarks:

Gartner's illustrated specimen (1968, pl. 22, fig. 11) is a poorly preserved Eiffellithus sp. asthe central area is almost closed one of the cross bars is longer than the other and has an Eiffellithus rim.

Gartner (1968) mentioned in page 27 that C. plicatus differs from C. amphipons (Bramlette and Martini 1964) Gartner(1968) by the large number of elements in the margin and in having a cluster of calcite rods at the intersection of the cross bars (stem) of the central area. The number of elements is highly variable in this species and is not a vital difference between the two species. Also the cluster of calcite rods can easily be broken or obscured by secondary calcite overgrowth.

Bukry's illustrated specimens of C. amphipons (1969, Pl. 26, figs. 8,9) are doubtful as the two specimens show a serrate outline.

Verbeek (1977) considered C. plicatus Gartner to be synonymous to C. litterarus (Górka) Manivit. His SEM-photographs for the distal side of C. amphipons (Pl. 5, fig. 1) and C. litterarus (Pl. 5, fig. 3) are similar. Also the SEM-photograph of the proximal side of C. litterarus Plate 2, Figure 2 represent a highly etched and overgrown specimen. The proximal cycle is etched and beneath it the proximal view of the distal cycle is visible and highly overgrown.

Genus: Helicolithus Noël 1970

Type Species: Discolithus anceps Górka 1957

Remarks:

Genus Helicolithus is distinguished from genus Eiffellithus by the presence of large and elongate elements, forming an inner cycle in the margin (which is more obvious on distal sides), the central cross bars (each bar is formed by two massive elements which are separated by a distinctive suture) are broader, generally the margin is broader (compared to the dimensions of the coccolith) and the absence of the plate like elements which fills the central area in the Eiffellithus group.

Helicolithus trabeculatus (Górka) Verbeek

1957 Discolithus trabeculatus Górka, p.277, pl.3, fig.9.

1966 Discolithus disgregatus Stover, Partim, p.142, pl.2, figs. 11a-b, 12a-b, non pl.8, fig.12.

1969 Chiastozygus disgregatus (Stover) Bukry, p.49, pl.27, figs.1-4.

1971 Eiffellithus trabeculatus (Górka) Reinhardt and Górka, Shafik and Stradner, p.83, pl.43, fig.2.

1972 Eiffellithus trabeculatus (Górka) Reinhardt and Górka, Roth and Thierstein, pl.12, figs.7-18.

1977 Helicolithus trabeculatus (Górka) Verbeek, p.90.

1981 Eiffellithus trabeculatus (Górka) Reinhardt and Górka, Smith, p.44, pl.6, figs.1-17.

1982 Helicolithus trabeculatus (Górka) Verbeek, Crux, pl.5.3, fig.4, pl.5,9, fig.15.

Figured material:

Plate 12, fig.2. UCL-2277-20 Length: 4.9 Um (LM)

Remarks:

This species has a distinctive inner cycle of about 6 long massive elements surrounding the central area which is occupied by a broad off-set cross bars without a stem at their intersection.

The species D. disgregatus which was described and illustrated by Stover (1966) shows the characteristic inner cycle with its 6 blocky elements and the broad off-set cross bars (Pl. 2, figs. 11,12) but his drawing (Pl. 8, fig. 12), does not show these features.

Helicolithus trabeculatus differs from H. anceps by its offset x-shaped cross bars and the narrower margin, with less elements in the outer cycle.

Occurrence:

This species is fairly common in the Late Cretaceous with a worldwide geographical distribution. Helicolithus trabeculatus has been reported under a variety of names (see the synonymy list) by different authors. It is found in the Upper Cretaceous sediments of all the studied sections (except Gebel Um El Ghanayem).

Helicolithus anceps (Górka) Noël

1957 Discolithus anceps Górka, p.252, pl.3, fig.4.

1970 Helicolithus anceps (Górka) Noël, p.41, pl.VIII, figs.1-5; pl. 1X, figs.1-2.

1971 Eiffellithus anceps (Górka) Reinhardt and Górka, Shafik and Stradner, p.82, pl.44, figs.1-4.

1982 Helicolithus anceps (Górka) Noël, Crux, pl.5.3, figs.7,8,11.

Remarks:

This species has a broad margin and wide central area which is occupied by a broad cross bar and an inner cycle of large elongate massive elements. A central stem may be present.

Occurrence:

Eiffellithus anceps (=Helicolithus anceps) was reported by Shafik and Stradner (1971, p. 82, 104) from the Maastrichtian of Drijeper-Donetz region of the USSR. Crux (1982, p. 107, 116) has reported this species from the Turonian to the Campanian from different localities in southeast England. This species is found (rare) in the Maastrichtian of Gebel Duwi section.

Genus: Discolithina Loeblich and Tappan 1963
Type species Discolithus vigintiforatus Kamptner 1948
Discolithina spiralis (Pienaar) Verbeek

1968 Discolithus spiralis Pienaar, p.365, pl.70, fig.3; pl.71, fig.4.

1977 Discolithina spiralis (Pienaar) Verbeek, p.88, pl.5, fig.5.

Figured material:

Plate 12, fig.3. UCL-2277-13, Length: 12.7 μm (LM)

Occurrence:

This species has been reported from the Maastrichtian sediments by few authors. Verbeek (1977, p. 25,88) has reported this species from the L. quadratus Zone of the El Kef section in Tunisia. This species is found in the L. quadratus Zone and N. frequens Zone at Gebel Tarbouli section. The absence of D. spiralis in the other sections is possibly due to dissolution which can easily effect this delicate form.

Family: EIFFELLITHACEAE Reinhardt 1965

Genus: Eiffellithus Reinhardt 1965

Type species: Zygolithus turriseiffeli Deflandre 1954

Remarks:

The genus Eiffellithus includes species with an elliptical basal disc having a thin rim composed of a cycle of imbricating elements. The central area is composed of:

1) two cross bars symmetrical, asymmetrical or slightly asymmetrical with respect to the major and minor axes of the ellipse. Each bar is formed of a bundle of small elongated elements. These cross bars form a long stem at the middle of the central area.

2) a plate of large elements which fills the central area partially or completely.

3) in distal view, a cycle of blocky elements attached to the rim may present.

<u>Eiffellithus</u> <u>turriseiffelii</u> (Deflandre) Reinhardt

1954 <u>Zygolithus</u> <u>turriseiffeli</u> Deflandre, Deflandre and Fert, p.149, pl.13, figs.15-16, text-fig.65.

1965 <u>Eiffellithus</u> <u>turriseiffeli</u> (Deflandre) Reinhardt, p.32.

1968 <u>Eiffellithus</u> <u>turriseiffeli</u> (Deflandre) Reinhardt, Gartner, partim. p.26, pl.2, figs. 22, 23, pl.3, figs.13a-c, pl.5, fig.19; pl.7, figs.5a-c; pl.9, figs.6-10; pl.13, figs.1a-c, 2a-c; pl.16, fig.1, pl.18, fig.11; pl.23, figs.7-11, pl.24, figs.1a-c, 2a-c, pl.25, figs.15,16; pl.26, figs.3a-c, 4a-c; not pl.16, fig.2; pl.17, figs.3a-c; pl.18, figs.9-10; pl.19, figs.1a-d, 2a-c, pl.22, fig.4.

1968 <u>Chiastozygus</u> <u>sp.</u> cf. <u>C.</u> <u>amphipons</u> (Bramlette and Martini) Gartner, p.26, pl.22, fig.11.

1980 <u>Eiffellithus</u> <u>turriseiffeli</u> (Deflandre) Reinhardt, Hattner and Wise, p.62.

Remarks:

This species can be distinguished from the other <u>Eiffellithus</u> species by its diagonal long thin cross bars, one of which is longer than the other. A long hollow stem rises from the intersection of the cross bars. The central area is partially or completely filled with a plate of large elements. The angle which the cross bars make with the short and long axes of the basal disc is highly variable. Verbeek (1977) mentioned that the longer bar of the central area always makes an angle of more than 20° with the long axes of the elliptical disc.

Occurrence:

This species has a world wide geographic distribution throughout the Late Cretaceous. This species is recorded in the Maastrichtian of all the studied sections (except Gebel Um El Ghanayem) in Egypt. It is very rare in the Early Palaeocene of Wadi Tarfa, Wadi Mellaha and Gebel Atshan. The presence of this Cretaceous form into the Early Palaeocene is due to reworking.

Eiffelllithus parallelus Perch-Nielsen

1973 *Eiffellithus parallelus* Perch-Nielsen, p.315, pl.6, figs.2,4, pl.10, figs.47-48.

1977 *Eiffellithus parallelus* Perch-Nielsen, Verbeek, p.89, pl.5, fig.10.

1978 *Eiffellithus parallelus* Perch-Nielsen, Perch-Nielsen et al., pl.1, figs.1, 2.

Figured material:

Plate 12, fig.1, UCL-2277-7 Length: 7.8 µm (LM)

Remarks:

Eiffellithus parallelus can be distinguished from *E. turriseiffelii* by its shorter and broader cross bars of the central area. Each bar is constructed of approximately three rows of small elements.

Occurrence:

This species has been recorded by Verbeek (1977, p. 25) in the top Maastrichtian (*Micula murus* Zone) of El Kef section Tunisia. Also it has been recorded by Perch-Nielsen *et al*. (1978 p. 344) in the *L. quadratus* Zone of Gebel Oweina (oppostie Esna) in the Nile Valley near Luxor, Egypt. *Eiffellithus parallelus* is fairly common in most of the Maastrichtian samples of the studied sections. It is recorded from Gebel Tarbouli (*Q. Trifidum* Zone-*N. freguens* Zone), Wadi Mellaha (*A. cymbiformis* Zone-*N. frequens* Zone), Gebel Duwi (*A. cymbiformis* Zone-*N, frequens* Zone) and Wadi Tarfa (*Q. trifidum* Zone-*L. quadratus* Zone).

Family: RHAGODISCACEAE Hay 1977

Genus: *Rhagodiscus* Reinhardt 1967

Type species: *Discolithus asper* Stradner 1963

Rhagodiscus angustus (Stradner) Reinhardt

1963 *Rhabdolithus angustus* Stradner, p.12, pl.5, figs.6-6a.

1966 *Parhabdolithus elongatus* Stover, partim, p.144, pl.6, figs.16, 17a-b, 18a-b, 19a-b non pl.9, fig.18.

1969 *Parhabdolithus fischeri* Bukry, p.53, partim, pl.29, fig.12, non pl.30, figs.1-3.

1971 *Rhagodiscus angustus* (Stradner) Reinhardt, p.23, pl.2, figs.1,2, text-fig.10.

1972 *Parhabdolithus angustus* (Stradner) Stradner, Adamiker, and Maresch, Roth and Thierstein, pl.6, figs.14-18; pl.7, fig.1.

1973 *Parhabdolithus angustus* (Stradner) Stradner, Adamiker and Maresch, Roth, p.725, pl.24, figs.4a-d.

1978 Parhabdolithus angustus (Stradner) Stradner, Adamiker and Maresch, Perch-Nielsen et al., pl.1, figs.17,18, pl.4, fig.8.

1980 Rhagodiscus angustus (Stradner) Reinhardt, Hattner and Wise, p.66, pl.29, fig.9, fig.30, fig.1.

1982 Parhabdolithus angustus (Stradner) Stradner et al., Crux, pl.5.8, fig.11, pl.5.6, fig.3.

Figured material:

Plate 2, fig.5. UCL 2141-34 Length: 8 µm (SEM)

Remarks:

This species is distinguished from Rhagodiscus splendens (Deflandre) Verbeek (1977) by its long parallel sided outline (with or without a ridge in the centre). Transitional forms between R. angustus and R. splendens occur in the Maastrichtian.

The specimen which was drawn in Stover's paper (1966, pl. 9, fig. 18) is not the same as R. angustus as it has an elliptical outline and different structure in the central area.

Bukry (1969) mentioned that Parhabdolithus fischeri differs from P. angustus (=Rhagodiscus angustus) by its broader rim, more elements in the rim and large number of small elements in the central area. His specimen (pl. 29, fig. 12) shows about the same number of elements as Parhabdolithus angustus (Pl. 29, figs. 9-11) and also its outline is parallel sided elongated compared to his other specimens (Pl. 30, fig. 1-3), which are elliptical in outline.

Rhagodiscus splendens (Deflandre) Verbeek

1953 Rhabdolithus splendens Deflandre, p.1786, figs.4-6.

1964 Cretarhabdus splendens (Deflandre) Bramlette and Martini, p.300, pl.3, figs.13-16.

1966 Parhabdolithus granulatus Stover, p.144, pl.6, figs.11-15, pl.9, fig.17.

1968 Actinozygus splendens (Deflandre) Gartner, partim, p.25, figs.15-16, pl.7, figs.1-2, pl.11, figs.15a-c, non pl.10, fig.1.

1969 Parhabdolithus fischeri Bukry, p.53, partim, pl.30, figs.1-3, non pl.29, fig.12.

1969 Parhabdolithus granulatus Stover, Bukry, p.53, pl.30, figs.4-7.

1977 Rhagodiscus splendens (Deflandre) Verbeek, p.94, pl.6, fig.9.

1980 Rhagodiscus splendens (Deflandre) Verbeek, Hattner and Wise, partim. p.67, pl.30, figs.3-4,6,8, non pl. 30, figs. 5,7.

Figured material

Plate 2, fig.6, UCL 1919-15 Length: 6.2 µm (SEM)

Remarks:

Rhagodiscus splendens differs from R. angustus by:

1) it has an elliptical to elongate elliptical shape, while R. angustus has an ellongate parallel sided shape.

2) Rhagodiscus splendens has a radial ridge extending from the margin into the central area. This structure is absent in the other species.

3) the rim of *R. splendens* is broader than the rim of *R. angustus* (particularly from the distal sides).

In poor preservation, where the central area is obscured due to overgrowth it is difficult to distinguish this species from the overgrown specimens of *A. regularis* as the characteristic central bars are obscured. The number of the elements of the distal cycle, the shape of the margin and the shape of the outline can be used to separate them. *Rhagodiscus splendes* differs from *Ahmuellerella regularis* by:

1) in the side view, (when the stem is upwards), the rim of the former species is higher.

2) in side view (stem upwards), the rim and the central area of *Rhagodiscus splendens* are convex, while in *Ahmuellerella regularis* the rim is flat to slightly concave towards its two far ends and the central area is convex.

3) the outline of *R. splendens* is elliptical to slightly elongate elliptical, while its subcircular to slightly elliptical in the other species.

4) in distal view the margin of *R. splendens* is thinner and its distal cycle is less imbricated than in *A. regularis*.

Gartner's specimen (1968, pl. 10, fig. 1) represents an overgrown specimen of *A. regularis* (Górka) Verbeek 1977.

Family: ZYGODISCACEAE Hay and Mohler 1967

Genus: *Tranolithus* Stover 1966

Type species: *Tranolithus manifestus* Stover 1966

Type species: <u>Tranolithus</u> <u>manifestus</u> Stover 1966

<u>Tranolithus</u> <u>phacelosus</u> Stover

1966 <u>Tranolithus</u> <u>phacelosus</u> Stover, p.146-147, pl.4, figs.23-25, pl.9, fig.7.

1966a <u>Discolithus</u> <u>orionatus</u> Reinhardt, p.42, pl.23, figs.22, 31-33.

1966b <u>Tranolithus</u> <u>orionatus</u> (Reinhardt) Reinhardt, p.522.

1969 <u>Zygodiscus?</u> <u>phacelosus</u> (Stover) Bukry, p.61, pl.35, fig.12.

1972 <u>Tranolithus</u> <u>orionatus</u> (Reinhardt) Reinhardt, Roth and Theirstein, pl.10, figs.11-15.

1976 <u>Tranoilithus</u> <u>orionatus</u> (Reinhardt) Reinhardt, Thierstein, p.352, pl.1, figs.7,8, pl.4, figs.11,12.

1980 <u>Zygodiscus</u> <u>orionatus</u> (Reinhardt) Smith, p.83, pl.16, figs.25-40.

1982 <u>Tranolithus</u> <u>orionatus</u> (Reinhardt) Reinhardt, Crux, pl.5.2, fig.11. pl.5.8, fig.25.

Figured material:

Plate 12, fig.6. UCL-2277-1 Length: 6.8 µm (LM)

Remarks:

The central area of this elliptical species is occupied by four quadrant or rectangular elements which fill the central area partially or completely. These four elements are more or less similar in diameter. The effect of overgrowth make them vary in dimensions. The margin of <u>T.</u> <u>phacelosus</u> has two cycles of elements. The distal cycle (which is broader than the proximal one) is composed of strongly imbricating elements. The proximal cycle is delicate, narrower than the distal cycle and constructed of slightly imbricating elements.

Tranolithus minimus (Bukry) Perch-Nielsen

1969 Zygodiscus minimus Bukry, p.61, pl.35, fig.9-11.

1973 Zygodiscus tarboulensis Shafik and Stradner, Perch-Nielsen, pl.10, figs.31,32.

1982 Zygodiscus minimus Bukry, Crux, pl. 5.8, fig.19, pl. 5.1, figs.19, 20.

1984 Tranolithus minimus (Bukry) Perch-Nielsen, p.44.

Figured material

Plate 2, fig.7. UCL-1872-18 Length: +3 μm (SEM)

Remarks:

This species is distinguished by the presence of two large plates almost closing the central area. These plates are separated by a set of transverse thin elements forming a bridge parallel to the short axis of the ellipse. This bridge is raised in the middle forming a hollow stem.

Dimensions: long diameter: 3.5 to 5 μm

Tranolithus tarboulensis (Shafik and Stradner) n. comb

1971 Zygodiscus tarboulensis Shafik and Stradner, p.91, pl.37, figs.1-4, text-fig. 5.

1978 Zygolithus tarboulensis Shafik and Stradner, Perch-Nielsen et al., pl.1, fig.24; pl.5, figs.8, 10,11.

Figured material:

Plate 2, fig.8. UCL-1877-9 Length: 4 μm (SEM)
fig.9. UCL-2139-22 Length: 5 μm (SEM)

Description:

The outline of T. tarboulensis is elliptical. In distal view, the distal cycle is composed of imbricated elements. The central area has a transverse bridge parallel to the short axis of the ellipse. This bridge is made up of elongate narrow elements and at its centre a small hollow stem is formed.

At each side of the central bridge, two long asymmetrical bars join near the hollow stem.

Dimensions: Long diameter: 4-6.5 Um

Remarks:

Tranolithus tarboulensis is distinguished by the presence of two asymmetrical elongate bars at each side of the open central area with one of these two bars always broader than the other. Overgrowth makes the bars of the central area appear to be two plates. This has made it difficult to distinguish this species from T. minimus. This species is transferred to genus Tranolithus due to the presence of plate-like bars in the central area and it differs considerably from the type species of the genus Zygodiscus, (Palaeocene/Eocene genus) which is Z. adamas a Tertiary species.

Occurrence:

Originally described from the Upper Maastrichtian of Gebel Tarbouli, Egypt by Shafik and Stradner (1971, p. 91). Perch-Nielsen et. al. (1978, p. 344) has recorded this species from the N. frequens Zone and L. quadratus Zone at Gebel Oweina (opposite Esna) in the Nile Valley near Luxor; Egypt. During the present work, this species is detected from Gebel Tarbouli (A. cymbiformis Zone to N. frequens Zone), Gebel Duwi (A. cymbiformis Zone-L. quadratus Zone). Also in L. quadratus Zone and N. frequens Zone from Gebel Atshan and Wadi Mellaha. The absence of this species at Um El Ghanayem section is due to the environmental stresses during this time period. Also the absence of this species at Wadi Tarfa section is possibly due to the poor presérvation which is quite common in most Maastrichtian samples.

Genus Glaukolithus Reinhardt 1964

Type species: Zygolithus diplogrammus Deflandre in Deflandre and Fert 1954

Remarks:

The species belonging to this genus have two closely spaced bars aligned with the short axis of the coccolith in the central area. These bars are thin, broad or very broad forming two plates filling the central area. This genus differs from genus Placozygus by its more strongly inclined elements of the distal cycle (in side view).

Glaukolithus diplogrammus (Deflandre) Reinhardt

1954 Zygolithus diplogrammus Deflandre, Deflandre and Fert, p.148, pl.10, fig.7, text-fig.57.

1966a Glaukolithus cf. diplogrammus (Deflandre) Reinhardt, p.41, pl.15, figs.6; pl.23, figs.25-28.

1968 Zygodiscus diplogrammus (Deflandre) Gartner, p.32, pl.14, fig.18; pl.17, figs.4a-d, pl.19, figs.3a-d, pl.21, figs.2a-d, pl.22, fig.7, pl.23, figs.12-14; pl.24, figs.6a-d, pl.25, figs.17,18.

1971 Zygolithus cf. diplogrammus Deflandre, Shafik and Stradner, p.92, pl.35, fig.4.

1978 Glaukolithus cf. diplogrammus (Deflandre) Reinhardt, Perch-Nielsen et al., pl.1, fig.26, pl.5, figs.6-7,9.

Figured material:

Plate 2, fig.10, UCL-2130-28 Length: 4 µm (SEM)
Plate 12, fig.8, UCL-2277-3 Length: 4.9 µm (LM)
Remarks:

The margin of this elliptical form shows two cycles of elements, the distal cycle is broader than the proximal one. Also, the distal cycle is strongly imbricating, particularly at the two far ends of the ellipse.

Glaukolithus diplogrammus differs from Glaukolithus compactus by:

1) the margin of the former species is narrower than the margin of the latter one.

2) the margin of G. compactus has a constant width while the margin of G. diplogrammus is broader at the two far ends of the margin.

3) the bars of the central area of G. diplogrammus is narrower than the bars of the central area of G. compactus.

4) there is no hollow stem in the central area of the *G. compactus* but in *G. diplogrammus* there is a hollow stem.

5) the presence of four sets of elements occupying the inner margin on both sides of the central bars, each set forms a triangular shape. This structure is absent in *G. compactus*.

Glaukolithus compactus (Bukry) Perch-Nielsen

1969 *Zygodiscus compactus* Bukry, p.59, pl.34, figs.1,2.

1981 *Zygodiscus compactus* Bukry, Smith, p.79, pl.15, figs.15-34. 22-34.

1981 *Zygodiscus compactus* Bukry, Crux, pl.5.1, figs.13,14,15.

1984 *Glaucolithus compactus* (Bukry) Perch-Nielsen, p.43 .

Description:

This elliptical species has a margin constructed of two cycles of elements. The distal cycle is broader and its elements are more imbricating than the proximal one. The central area is almost filled with two closely spaced broad bars. A slit-like opening may be present between the two bars. The stem is absent.

Figured material:

Plate 2, fig.11. UCL-1870-4. Length: +5 μm (SEM)
fig.12. UCL-1870-2. Length: 7 μm (SEM)
Plate 12, fig.7. UCL-2278-5. Length: 7.8 μm (LM)

Genus: Placozygus Hoffman 1970

Type species: Glaukolithus fibuliformis Reinhardt 1964

Placozygous sigmoides (Bramlette and Sullivan) Romein

1961 Zygodiscus sigmoides Bramlette and Sullivan, p.149, pl.4, figs.11a-e.

1964 Zygodiscus sigmoides Bramlette and Sullivan, Bramlette and Martini, p.303, pl.4, figs.3-5.

1979 Placozygus sigmoides (Bramlette and Sullivan) Romein, p.117, pl.1, fig.8.

Figured material:

Plate 2, fig.13. UCL-1892-8. Length: + 8.3 μm (SEM)
fig.14. UCL-1892-5. Length: 10 μm (SEM)

Occurrence:

Placozygus sigmoides is one of the few species which crossed the Cretaceous-Tertiary boundary. This species was recorded by many authors in the Upper Maastrichtian and the Early Tertiary. Perch-Nielsen et al. (1978, p. 344, 346) has recorded this species in N. frequens Zone (Late Maastrichtian) and from NP4 (equal to NP4a and NP4b, this work) to NP9 from Egypt. Romein (1979, p. 25, 35, 118) has reported P. sigmoides in Israel and Spain from Cruciplacolithus primus Zone (Early Danian) to the T. contortus Zone (Early Eocene), also from Scandinavia in the Early Palaeocene. Steinmetz and Stradner (1984, p. 691-693) has recorded this species in the Palaeocene from the Angola Basin in the southeast Atlantic Ocean. In this study, this species is recorded from Gebel Tarbouli (Q. trifidum, N. frequens, and NP10 Zones), Wadi Mellaha (N. frequens Zone-NP10), Gebel Atshan (NP3-NP10), Gebel Duwi (NP3-NP7/8), Gebel UM El Ghanayem (NP4a-NP9) and Wadi Tarfa (NP3-NP10).

Placozygus fibuliformis (Reinhardt) Hoffman

1964 Glaukolithus ? fibuliformis Reinhardt, p.758, pl.1, fig.4.

1964 Zygodiscus spiralis Bramlette and Martini, p.303, pl.4, figs.6-8.

1966a Glaukolithus fibuliformis Reinhardt, Reinhardt, p.41, pl.9, figs.1-3, pl.22, fig.22.

1969 Zygodiscus fibuliformis (Reinhardt) Bukry, p.59, pl.34, figs.9,10.

1970b Placozygus fibuliformis (Reinhardt) Hoffman, p.1004, pl.1, figs.1-4.

1977 Zygodiscus spiralis Bramlette and Martini, Verbeek, p.98, pl.7, figs.11-12.

Description:

This species has an elliptical outline. The margin is constructed of two cycles of elements. The distal cycle is robust, the elements are slightly imbricating in distal view and almost vertical in side view. The proximal cycle is narrower than the distal one, the elements are thin and imbricating in clockwise direction. The central bars show four triangular elements at their ends, and at the centre a stem is present.

Figured material:

Plate 2, fig.15, UCL-1870-3. Length: 5 μm (SEM)
Plate 3, fig.1, UCL-1870-8. Length: 5 μm (SEM)

Remarks:

Placozygus fibuliformis differs from Glaucolithus compactus by:

1) the bars of the central area are thinner but broaden towards the margin in the former species this is due to the presence of the triangular elements at the ends of the bars. In Glaucolithus compactus the bars are broader with constant width with no trangular elements at their ends.

2) the stem is always present in Placozygus fibuliformis while its absent in the Glaucolithus compactus.

3) in side view, the distal cycle of the former species is almost vertical while its strongly inclined in the later species.

Placozygus fibuliformis differs from Glaucolithus diplogrammus by:

1) the margin of the former species is broader, with constant width than the margin of the latter species.

2) in distal view, the elements of the distal cycle of P. fibuliformis are less imbricating than those of G. diplogrammus. Also in side view the elements of the distal cycle of the former species are almost vertical, while they are strongly inclined in the latter species.

Occurrence:

This species has a well documented worldwide geographic occurrence throughout the Late Cretaceous. Also it is found in the Maastrichtian samples of all the studied sections from Egypt.

Genus: Reinhardtites Perch-Nielsen 1968

Type species: Rhabdolithus anthophorus Deflandre 1959

Reinhardtites levis Prins and Sissingh

1977 Reinhardtites levis Prins and Sissingh, p.61, pl.1, figs.1-3.

1977 Reinhardtites anthophorus (Deflandre) Perch-Nielsen, Verbeek, p.91, pl.6, figs.1,2.

1980 Zygodiscus elegans Gartner, Hattner and Wise, p.69, pl.34, figs.8-9, pl.35, figs.1-7, non pl.43, figs.4-8.

1982 Reinhardtites levis Prins and Sissingh, Crux, pl.5.2, fig.4, pl.5.8, figs.27-28.

Figured material:

Plate 3, fig.2. UCL-2136-31 Length: 9 μm (SEM)
fig.3. UCL-2136-6 Length: 8 μm (SEM)
Plate 12, fig.19 UCL-2277-32 Length: 9.8 μm (LM)

Remarks:

Deflandre's specimens (1959, pl. 1, figs.21-22) of Rhabdolithus anthophorus were in side view which does not represent the proximal or the distal sides of the coccolith. Prins and Sissingh (1977) have considered R. anthophorus as those specimens with a long flaring spine.

Reinhardtites anthophorus is not seen in our Upper Cretaceous samples. R. levis can be distinguished from R. anthophorus by its broader smooth plate in the central area, the two openings of the central area are smaller and the top of the distal spine is not, or is only slightly flaring.

Occurence:

This species has a relatively short stratigraphic range through the Late Campanian and Maastrichtian (Sissingh and Prins 1977, p. 61 and Crux 1982, p. 107, 109). This species is found at Wadi Mellaha section (*A. cymbiformis* Zone), at Gebel Tarbouli (*Q. trifidium* Zone and *A. Cymbiformis* Zone) and at Wadi Tarfa in (*Q. trifidium*, *A. cymbiformis* Zones.

Genus: *Zeugrhabdotus* Reinhardt 1965

Type species: *Zeugrhabdotus erectus* (Deflandre in Deflandre and Fert 1954) Reinhardt 1965

Zeugrhabdotus embergeri (Noël) Perch-Nielsen

1958 *Discolithus embergeri* Noël, p.164, pl.1, figs.5, 6a-e, 7a-b, 8.

1964 *Zygodiscus? pseudonthophorus* Bramlette and Martini, p.303, pl.3, fig.17, pl.4, figs.17,18.

1968 *Zygodiscus lacunatus* Gartner, p.33, pl.17, figs.6a-d; pl.18, figs.15,16; pl.19, figs.5a-d, pl.23, figs.15,16, pl.24, figs.3a-d.

1984 *Zeugrhabdotus embergeri* (Noël) Perch-Nielsen, p.44.

Figured material:

Plate 12, fig.9. UCL-1861-2. Length: 11.7 µm (LM)

Remarks:

Zeugrhabdotus embergeri is a large elliptical form with a massive high margin and a transverse bar supporting a stem. This species shows variation in size, the width of the central bar, the diameter of the stem and the width of the rim. In the LM/CP the bar shows high birefringence taking the shape of a lens. Also the margin is very bright.

This species is not assigned to the genus Parhabdolithus because it has evolved from Zeugrhabdotus erectus in the Kimmeridgian, and the type species of the genus Parhabdolithus is P. liasicus which has an outer wall constructed of vertical elements.

Occurrence:

This species has stratigraphic range from the Kimmeridgian to the Maastrichtian. It is found in the Maastrichtian sections from Egypt (except Gebel Um El Ghanayem section).

Genus Neochiastozygus Perch-Nielsen 1971b

Type species: Neochiastozygus perfectus Perch-Nielsen 1971b.

Remarks:

The species belonging to genus Neochiastozygus have an elliptical or elongate elliptical outline in plan view. The margin consists of two cycles (rim and the wall) and central cross bars. These cycles are constructed of imbricating and inclined elements. Each bar of the central area is composed of two long laths.

Genus _Zygolithus_ Kamptner 1955 was used for species with an elliptical outline and a central area spanned by one or two cross bars. Genus _Heliorthus_ Bronniman and Stradner, 1960 was used for species having an x-shaped structure spanning the central opening. Genus _Neochiastozygus_ is restricted to species with a margin constructed of two closely appressed cycles of elements and x-shaped cross bars, where each bar is formed of two long laths (Fig. 49).

Genus _Neochiastozygus_ differs from the genus _Neococcolithes_ Sujkowski (1931) by

1) the margin of the former genus is composed of two appressed cycles of elements, while in the latter genus has single cycle in the margin.
2) the cross bars have a split appearance in the LM/CP, in the _Neochiastozygus_ species, while the cross bars of species of _Neococcoliths_ do have a solid appearance in cross-polarised light.

Neochiastozygus perfectus Perch-Nielsen

1971b _Neochiastozygus perfectus_ Perch-Nielsen, p.63, pl.6, figs.1,2, pl.7, figs.24,25.

1977 _Neochiastozygus perfectus_ Perch-Nielsen, Perch-Nielsen, pl.38, figs. 6, 10, 12.

1978 _Neochiastozygus perfectus_ Perch-Nielsen, Perch-Nielsen et al., pl.10, figs.43, 44; pl.21, fig.3.

1978 _Neochiastozygus concinnus_ (Martini),Abdelmalik et. al., p.227, pl.2 figs. 11a-b, pl. 3, figs.1a-b.

Figured material:

Plate 3, fig.8 UCL.2068-23, Length: + 5 µm (SEM)
fig.9 UCL.2062-24, Length: + 5 µm (SEM)

Remarks:

Elongate elliptical outline in plan view. The margin is constructed of two closely appressed cycles of elements. The wall is composed of 40 to 64 inclined (clockwise in distal view) elements. The rim is slightly thicker and higher than the wall. The central area is spanned by an x-shaped cross bars, each one composed of two elongated elements slightly thickened near the wall. The diameter (length) of this species is 6-9 Um.

Neochiastozygus perfectus differs from Neochiastozygus junctus (Bramlette and Sullivan) Perch-Nielsen by:

1) the size of the former species is less than the latter one

2) in N. perfectus the angle which the cross bars make with the short axis of the ellipse is more than the angle which the cross bars of N. junctus make with the short axis of the ellipse.

3) the number of elements of the rim and the wall of N. perfectus is less than the number of elements of the margin of N. junctus.

Occurrence:

This species is only recorded throughout the Palaeocene (NP3 to NP9). Romein (1979, p. 42, 43), has recorded N. perfectus from the C. tenuis Zone (=NP2 and NP3) and the E. macellus Zone NP4 (equal NP4a and NP4b, this work) of Klintholm and Bredstrup Klint sections in Denmark. Perch-Nielsen et. al. (1978, p. 346) has reported this species from the Late Palaeocene (D. multirachiatus Zone) at Gebel Oweina section near

Luxor, Egypt. Perch-Nielsen (1981a, p. 845) has considered the stratigraphic range of this species from the top of NP4 Zone to the top of NP6 Zone.
In this work the earliest occurrence of N. perfectus is detected in the lower part of NP4a (equal to the lower part of NP4) Zone at Gebel Duwi section. The highest occurrance of this species is found in NP9 Zone (Late Palaeocene) Zone at Gebel Atshan and in NP10 Zone in Wadi Mellaha and Gebel Duwi sections.

Neochiastozygus junctus (Bramlette and Sullivan) Perch-Nielsen

1961 Zygolithus junctus Bramlette and Sullivan, p.150, pl.6, figs.11a-6.

1967 Heliorthus junctus (Bramlette and Sullivan) Hay and Mohler, p.1533.

1971b Neochiastozygus junctus (Bramlette and Sullivan) Perch-Nielsen, p.61, pl.4, figs.7,8,pl.7, figs.18,19.

1978 Neochiastozygus junctus (Bramlette and Sullivan) Perch-Nielsen , Perch-Nielsen et al., pl.10, figs.28,29.

1979 Neochiastozygus junctus (Bramlette and Sullivan) Perch-Nielsen, Okada and Thierstein, pl.7, figs.3a-b, pl.17, fig.12.

Figured material:

Plate 3, fig.10, UCL-2076-10, Length: +7 µm (SEM)

Remarks:

Large elliptical species (length 9.5-12.5 µm) with a central area spanned by a narrow cross bar which makes a small angle with the short axis of the ellipse. The number of elements in the rim is about 100. This species is very similar in construction to Neochiastozygus perfectus but differs by its larger size, the presence of more elements in the margin, the smaller angle which the bars of the central are make with the short axis of the coccolith and the presence of a rectangular structure in the central part of the cross bars in the Light Microscope, phase contrast.

Occurrence:

Many authors (Bramlette and Sullivan 1961, Hay and Mohler 1967 and Perch-Nielsen 1978, 1981) have recorded this species in the Late Palaeocene and the Early Eocene (top of NP7/8-NP11). Romein (1979, p. 25) has reported this species from the Caravaca section (S.E. Spain) in the base of the F. tympaniformis Zone (equal the lower part of F. tympaniformis Zone NP5/6, this work) to the D. multiradiatus Zone (Late Palaeocene). Here, N. junctus is not found below the D. multiradiatus Zone. Also it is common at the Early Eocene (NP10). It is recorded from Gebel Um El Ghanayem (NP9), Gebel Atshan (NP9-NP10), Gebel Duwi (NP9-NP10), Gebel Tarbouli (NP10) and Wadi Mellaha (NP9-NP10).

Neochiastozygus distentus (Bramlette and Sullivan) Perch-Nielsen

1961 Zygolithus distentus Bramlette and Sullivan, p.150, pl.6, figs.4a-c-7.

1971b Neochiastozygus distentus (Bramlette and Sullivan) Perch-Nielsen, p.61, pl.4, figs.1-4.

1977 Neochiastozygus distentus (Bramlette and Sullivan) Perch-Nielsen, Perch-Nielsen, partim, pl.39, figs.2,5,8, non pl.38, figs.3-4,8.

1978 Neochiastozygus distentus (Bramlette and Sullivan) Perch-Nielsen , Perch-Nielsen et al., pl.10, figs.24-27, 30-33, pl.21, figs.4,8,11,15-19.

Figured material:

Plate 3, fig.14. UCL-2051-21. Length: 6 µm (SEM)

Remarks:

The species has a very broad wall and a narrow rim. The rim and the wall have the same number of elements about 44 to 54. The central area is spanned by short and wide cross bars. In distal view, the elements of the rim are imbricated anti-clockwise and the elements of the wall are imbricated clockwise.

Neochiastozygus distentus differs from Neochiastozygus perfectus Perch-Nielsen by:

1) the central area of the former species is smaller than the central area of the latter species

2) the cross bars of the central area of N. distentus are broader, and shorter than the central cross bars of N. perfectus.

3) the angle which the central cross bars of N. distentus make with the short axis of the coccolith is larger than the angle which the central cross bars of N. perfectus make with the short axis.

4) the central cross bars of N. distenctus have a constant width, while the cross bars of N. perfectus are broader close to the margin.

5) the margin (rim and wall) of N. distentus is broader than the margin of N. perfectus.

Perch-Nielsen (1977) illustrated three specimens (pl.38, figs.3,4,8) as N. distentus. These specimens do not have the distinctive characters of this species (broader margin, wide and short cross bars). Also the specimen in pl. 38, figure 4 has a cross bar which is broader near the margin. This specimen is considered in this study N. concinnus.

Occurrence:

This species has been reported by Romein (1979, p. 25, 35, 135) from Carvaca section (S.E. Spain) and Nahal Avdat throughout the *F. tympaniformis* Zone NP5 (equal to the lower part of NP5/6, this work) to *T. contortus* Zone (NP10). Perch-Nielsen (1981a, p.845) has mentioned this species has its first appearance in the *D. mohleri* Zone (NP7/8). In Egypt, the species is rare from the *F. tympaniformis* Zone (NP5) to *D. multiradiatus* Zone (NP9) in Gebel Um El Ghanayem section. In Wadi Mellaha section is observed only throughout the *D. multiradiatus* Zone (NP9) to the *T. contortus* Zone (NP10). Also, *N. distentus* is found in the *D. multiradiatus* Zone in Gebel Atshan section and from *F. tympaniformis* Zone (NP5/6) to *T. contortus* Zone (NP10) in Wadi Tarfa section.

Neochiastozygus concinnus (Martini) Perch-Nielsen

1961 *Zygolithus concinnus* Martini, p.18, pl.3, fig.35, pl.5, fig.54.

1964 *Zygolithus concinnus* Martini, Bramlette and Martini, p.304, pl.4, figs.13,14, pl.7, figs.3a-b.

1967 *Heliorthus concinnus* (Martini) Hay and Mohler, p.1533, pl.199, figs.16-18, pl.201, figs.6,7,10.

1969b *Heliorthus concinnus* (Martini) Hay and Mohler, Perch-Nielsen, p.62, pl.5, figs.6-8.

1971a *Neococcolithes concinnus* (Martini) Perch-Nielsen, fig.21.

1971b *Neochiastozygus concinnus* (Martini) Perch-Nielsen, p.59, pl.4, fig.6, pl.7, figs.4-6.

1977 *Neochiastozygus concinnus* (Martini) Perch-Nielsen, pl.39, fig.7.

not 1979 <u>Neochiastozygus concinnus</u> (Martini) Perch-Nielsen, Okada and Thierstein, pl.7, fig.1a-b, pl.17, figs.9-10.

Figured material:

Plate 3, fig.13. UCL 1972-24. Length: 6 µm (SEM)

Remarks:

This species has an elliptical outline in plan view. The wall and the margin are each constructed of 40 to 68 elements. The elements of the rim imbricate in an anti-clockwise direction on the distal side and the elements of the wall imbricate and incline clockwise on the distal side. The rim is higher and thicker than the wall. The cross bars of the central area are long, making a large angle with the short axis of the ellipse, broader close to the margin of the coccolith. A rectangular or square structure can be observed in the centre of the cross bars in the LM or the SEM. The length is 5-9 µm.

<u>Neochiastozygus concinnus</u> differs from <u>Neochiastozygus perfectus</u> by:

1) in the former species the angle which the cross bars make with the short axis of the coccolith is larger than the angle which the cross bars of <u>N. perfectus</u> make with the short axis of the ellipse.

2) the presence of a rectangular shape at the centre of the cross bars in <u>N. concinnus</u> is absent in the <u>N. perfectus.</u>

3) in <u>N. concinnus</u> the width of the cross bars near the margin is more than the width of the cross bars near the margin of the <u>N. perfectus.</u>

Okada and Thierstein's specimens (1979, pl.7, fig.1) and (pl. 17, fig.10) are <u>N. modestus</u> as the cross bars of the central area are broad with constant width. Specimen (pl. 17, figure 9) is highly dissolved and difficult to identify.

Neochiastozygus modestus Perch-Nielsen

1971b Neochiastozygus modestus Perch-Nielsen, p.62, pl.5, figs.5-8, pl.7, figs.22-23.

1977 Neochiastozygus modestus Perch-Nielsen, Perch-Nielsen, pl.38, fig.11, pl.39, figs.1,3-4,6,9; pl.40, figs.7-10.

Figured material:

Plate 3, fig.12. UCL-2037-16.Length: 5 μm (SEM)

Remarks:

The elements of the rim are elongate rhombohedal in shape and imbricate in an anti-clockwise direction. The elements of the wall have the same shape as the rim elements but they imbricate in a clockwise direction. The number of elements of the wall and the rim are the same and equal about 40 in each cycle. Each bar of the cross bars is composed of two laths. Small protrusions extending from the wall into the central area may be the remains of an etched plate or overgrowth. The diameter (length); 3.5-6 μm.

Neochiastozygus modestus differs from Neochiastozygus distentus by:

1) the central area of the former species is larger than the central area of the latter species.

2) the margin of N. modestus is narrower than the margin of the N. distentus.

3) the number of elements in the margin of the N. modestus is less than the number of elements in the margin of the N. distentus.

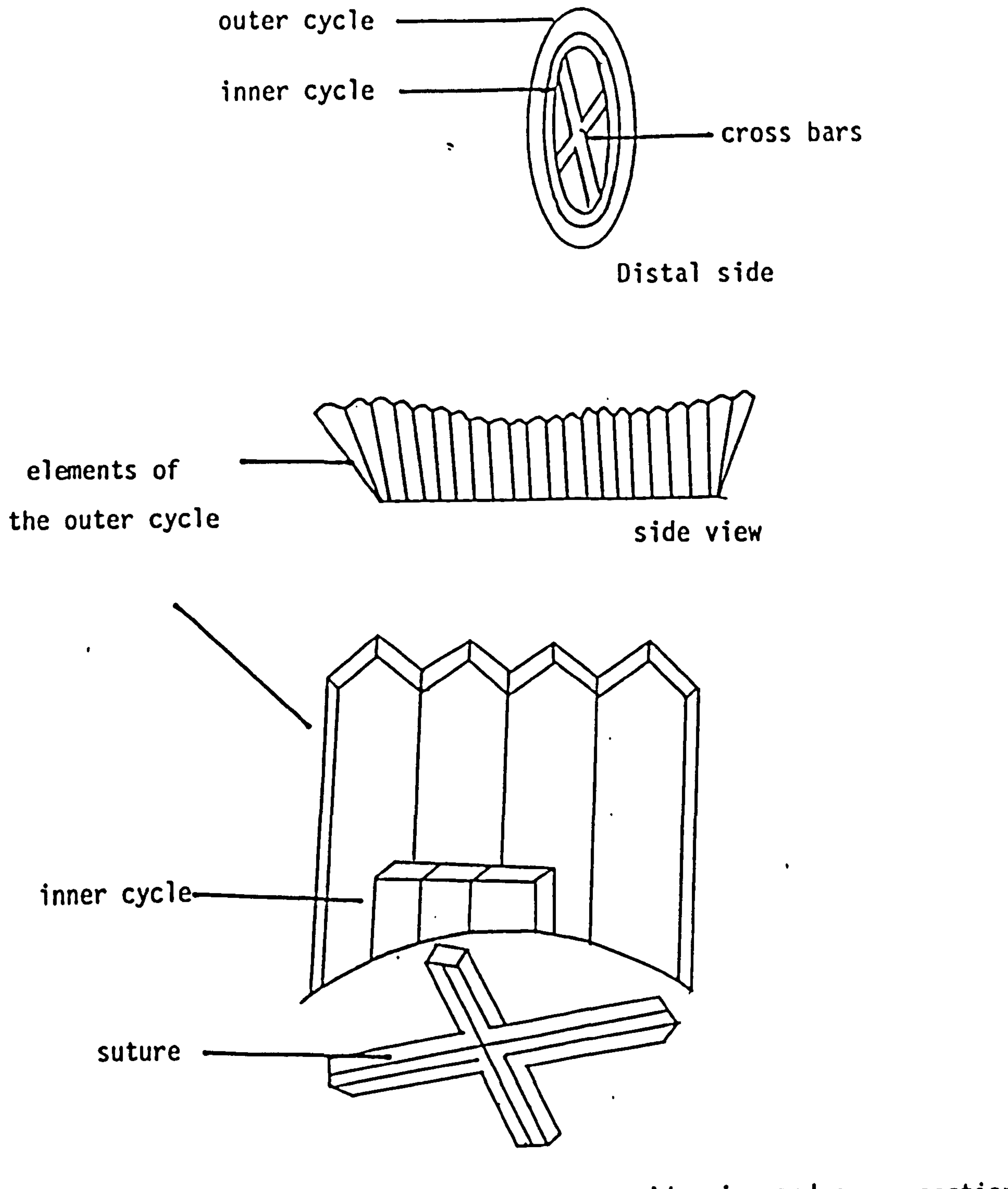


Fig.50 -Schematic drawings of the significant features of the genus Diadochiastozygus n.gen.

Neochiastozygus modestus differs from Neochiastozygus concinnus by

1) the cross bars of the central area of the N. modestus have a constant width, while they are wider near the margin in N. concinnus.

Occurrence:

Romein (1979) has recorded this species from the P. dimorphosus Zone (top of NP1) from Caravaca Section (S.E. Spain). This early first appearance is not previously recorded for this species. In Egypt, throughout this investigation, this species is recorded from Gebel Um El Ghanayem (NP4a), Gebel Atshan (NP4a), Wadi Mellaha (NP4a-NP5/6), Gebel Duwi (NP3-NP7/8) and Wadi Tarfa (NP5/6).

Genus: Diadochiastozygus n. gen.

Type species: D. imbriei (Haq and Lohmann) n. comb.

Derivation of name: From the Greek "diadochos" = succeeding.

Diagnosis:

This genus is distinguished by the vertical elements of the outer cycle of the margin.

Description:

The species are elliptical to elongate elliptical in plan view. The margin is narrow and the central area is occupied by x-shaped cross bars. The margin is constructed of two cycles of elements. These cycles are closely appressed. The elements forming the outer cycle arevertical and non-imbricating. The inner cycle is shorter in length than the outer one and constructed of slightly inclined and imbricating elements (Fig. 50).

Remarks:

This genus is introduced here to include forms with a rim (outer cycle) formed of a cycle of vertical non-imbricated elements which were referred to genus Neochiastozygus in the past. These species are D. eosaepes, D. saepes and D. imbriei. These species have a short stratigraphc range in the Early Palaeocene (in the NP3 and NP4a Zones in Egypt and in the NP3 and NP5 Zones elsewhere).

Diadochiastozygus eosaepes (Perch-Nielsen) n. comb.

1981 Neochiastozygus eosaepes Perch-Nielsen, p.837, pl.5, figs.9-13.

Figured material:

Plate 3, fig.7. UCL-2067-22. Length: 5 μm (SEM)

Occurrence:

This species is described by Perch-Nielsen (1981a) from Hvallose, boring, fylland, Denmark in the Chiasmolithus danicus Zone (NP3). During this work D. eosaepes is found rare in the E. macellus Zone (NP4a) at Gebel Duwi section.

Diadochiastozygus saepes (Perch-Nielsen) n. comb.

1971a Heliorthus? saepes Perch-Nielsen, fig.21.

1971b Neochiastozygus saepes (Perch-Nielsen) Perch-Nielsen, p.64, pl.6, figs.3-6, pl.7, figs.7-9.

Figured material:

Plate 3, fig.4. UCL-2067-34 Length: 5 µm (SEM)

Remarks:

The species have a subelliptical outline in plan view. The margin consists of an inner cycle or wall and an outer one or rim. The wall and the rim are closely appressed. The rim is composed of about 50 vertical or nearly vertical elements and is serrate and higher than the wall (about twice the height of the wall). The serration and the difference in the height of the margin (the wall and the rim) may be due to dissolution as the specimens investigated in the SEM in this project were poorly preserved. The rim is constructed of elongated vertical, rhombohedral elements with pointed serrate ends and straight sutures between the non imbricating elements. The wall is constructed of slightly inclined clockwise elements (on the distal side) which form an inner cycle thinner and lower than the height of the outer cycle (rim) of the margin. The central area is spanned by x-shaped cross bar, each one composed of two long elements parallel to the long axis of the bar and separated from each other by a long suture.

Occurrence:

This species has a distinctive short stratigraphic range in the Lower and Upper Palaeocene. Romein (1979, p. 25, 35) has recorded this species from the C. tenuis Zone (=NP2 and NP3) from the Caravaca section (S.E.Spain) and in the same zone from Nahal Avdat Section (Israel). Perch-Nielsen (1981a, p. 845) has discussed the evolutionary lineages between this species and the other members of Neochiastozygus genus. She mentioned that the stratigraphic range of this species is from the E. macellus Zone (NP4) to F. tympaniformis Zone (NP5). Here this species is found (rare) in the E. macellus Zone (NP4a) only in Gebel Duwi, and Gebel Um El Ghanayem sections.

<u>Diadochiastozygus</u> <u>imbriei</u> (Haq and Lohmann) n. comb

1976 <u>Neochiastozygus</u> <u>imbriei</u> Haq and Lohmann, p.183, pl.4, fig.3.

1977 <u>Neochiastozygus</u> <u>imbriei</u> Haq and Lohmann, Perch-Nielsen, pl.38, figs.5,9, pl.49, figs.20,21.

1979 <u>Neochiastozygus</u> <u>imbriei</u> Haq and Lohmann, Okada and Thierstein, pl.7, figs.2a-b; pl.17, fig.11.

Figured material:

Plate 3, fig.5. UCL-2067-31 Length: 4 µm (broken specimen)
fig.6 UCL-2-67-32 Length: 4 µm (SEM)

Remarks:

Forms have a long-elliptical outline in plan view. The margin is constructed of two closely appressed cycles of elements. The wall or the inner cycle composed of inclined elements and the rim also composed of a nearly vertical element make this cycle broader and higher than the wall. The number of elements in the rim is about 70. The cross bars of the central area are long and diagonal.

Haq and Lohmann (1976) described the orientation of the cross bars of the central area as parallel to the major axes of the ellipse. No specimens were found with this orientation but all of the specimens have a slightly deviated cross bar away from the long and the short axes of the ellipse. Even their specimen (1976, pl.IV, fig.3) shows a diagonal cross bar.

Occurrence:

This species has a distinctive short stratigraphic range in the Lower Palaeocene. This species is found in the E. macellus Zone (NP4a) of Gebel Duwi and in C. danicus Zone (NP3) at Wadi Tarfa section.

Genus Neococcolithes Sujkowski 1931

Type species: Neococcolithes lososnensis Sujkowski 1931

Neococcolithes protenus (Bramlette and Sullivan) Hay and Mohler

1961 Zygolithus protenus Bramlette and Sullivan, p.150, pl.6, figs.15a-b.

1967 Neococcolithes protenus (Bramlette and Sullivan) Hay and Mohler, p.1533, pl.199, figs.19-21, pl.201, fig.9.

1979 Neococcolithes protenus (Bramlette and Sullivan) Hay and Mohler, Romein, p.138.

Figured material:

Plate 3, fig.15. UCL-1995-19 Length: 5 μm (SEM).

Occurrence:

This species was only recorded from the D. multiradiatus Zone (Late Palaeocene) by Bramlette and Sullivan (1961, p. 150) from Lodo Formation of California and by Hay and Mohler (1967, p. 1511, 1533) at Pont Labau (Paris). In Egypt, during this work, this species is observed in the T. contortus Zone (Early Eocene) at Wadi Mellaha and Gebel Tarbouli. At Gebel Um El Ghanayem, this species is rare in NP7/8 and NP9 Zones.

Genus: Lophodolithus Deflandre 1954

Type species: Lophodolithus mochlophorus Deflandre 1954

Lophodolithus nascens Bramlette and Sullivan

1961 Lophodolithus nascens Bramlette and Sullivan, p.145, pl.4, figs.7-8.

1971 Lophodolithus nascens Bramlette and Sullivan, Perch-Nielsen, p.41, pl.37, figs.1-4.

1977 Lophodolithus cf. L. nascens Bramlette and Sullivan, Perch-Nielsen, pl.27, fig.7, pl.28, fig.5.

1979 Lophodolithus nascens Bramlette and Sullivan, Romein, p.140, pl.8, fig.4.

Figured material:

Plate 4, fig.1. UCL-2084-17. Length: 10 μm (SEM)

Family MICRORHABDULACEAE Deflandre 1963

Remarks:

This family includes calcareous nannofossils which are formed of an elongate rod without a basal disc.

Genus: Microrhabdulus Deflandre 1959

Type species: Microrhabdulus decoratus Deflandre 1959

Remarks:

The species belonging to this genus are formed of straight or slightly curved rods. These rods are composed of small elongate calcareous elements which are oval, circular, subcircular or square in cross-section.

Microrhabdulus belgicus Hay and Towe

1963 Microrhabdulus belgicus Hay and Towe, p.95, pl.1.

1968 Microrhabdulus belgicus Hay and Towe, Gartner, p.44, pl.6, figs.13a-c, pl.10, figs. 21-23, pl.12, figs.13a-c; pl.22, fig.27.

1969 Microrhabdulus belgicus Hay and Towe, Bukry, p.66, pl.39, figs.9-11.

1971 Microrhabdulus belgicus Hay and Towe, Shafik and Stradner, p.84, text-fig.3.

1977 Microrhabdulus belgicus Hay and Towe, Verbeek, p.100, pl.8, fig.6.

1980 Microrhabdulus belgicus Hay and Towe, Hattner and Wise, p.65, pl.26, figs.1-3.

1982 Microrhabdulus belgicus Hay and Towe, Crux, pl.5.5, fig.17.

Figured material:

Plate 4, fig.2. UCL-1919-33. Length: 10 µm (SEM)

Remarks:

This species is distinguished by the broad middle part of its rod which gradually narrow towards the two far ends. It has cycles of small blocky elements along the axis of the rod and an oval, rectangular or square shaped cross section.

Microrhabdulus decoratus Deflandre

1959 Microrhabdulus decoratus Deflandre, p.140, pl.4, figs.1-5.

1964 Microrhabdulus decoratus Deflandre, Bramlette and Martini, p.314, pl.6, figs.1-2.

1966 Microrhabdulus decoratus Deflandre, Stover, p.152, pl.7, figs.15,16.

1968 Microrhabdulus decoratus Deflandre, Gartner, p.44, pl.2, fig.4, pl.5, fig.3, pl.6, figs.12a-c, pl.28, fig.1.

1968 Microrhabdulus stradneri Bramlette and Martini, Gartner, p.44, pl.12, figs.14a-c.

1980 Microrhabdulus decoratus Deflandre, Hattner and Wise, p.65, pl.26, fig.4.

1982 Microrhabdulus decoratus Deflandre, Crux, pl.5.10, figs.4-5.

Description:

Microrhabdulus decoratus is formed of a long rod constructed of elongate rectangular elements which are arranged around the long axis of the rod. These rectangular elements have one or both of the ends bifurcate.

Figured material:

Plate 4, fig.3. UCL-1934-8 (SEM)

Remarks:

In cross-polarised light, when the long axis of *M. decoratus* is parallel to either nicol, two closely spaced rows of bright (more or less) rectangular plates are formed. Every bright rectangular plate in each row is opposite to another one from the other row. When the long axis of the rod is slightly rotated from the vibration direction of either nicol two rows of alternate rectangular plates become bright and dark. The bright rectangular plate of one row is opposite to a dark plate from the other row.

Bramlette and Martini (1964, p. 316) separated *M. stradneri* from *M. decoratus* through their behaviour in cross-polarised light. As the former species shows a bright triangular plate while the latter shows rectangular plates. Verbeek (1977, p. 100) considered the two species to be conspecific because most of the specimens he found were intermediate forms and the presence of a bright triangle or rectangular plate in cross-polarised light depends on the orientation of elements. Also he found that in the SEM both show the same construction of elements.

In this study some specimens have the elongate rectangular elements with one of the two long edges longer than the other which may be the reason for the presence of bright triangles in the cross polarised light.

Microrhabdulus elongatus Gartner

1964 Microrhabdulus ?sp. Bramlette and Martini, p.316, pl.6, fig.5.

1968 Microrhabdulus? elongatus Gartner, p.44, pl.9, fig.21; pl.12, figr.15a-c.

1977 Microrhabdulus elongatus Gartner, Verbeek, p.101.

Description:

The rod is formed of elongate slightly twisted elements which give the rod a spiral shape. The two far ends of the rod are pointed.

Remarks:

In the LM/CP when the rod is parallel to one of nicols, two rows formed of short parallel inclined bright lines result. The two rows are separated by a dark line.

The generic name of this species was a matter of question in Bramlette and Martini (1964) and Gartner (1968) because of the presence of a disc at one end of the rod. Gartner's illustrated specimens (1968, pl. 9, fig. 21 and pl. 12, fig. 14) do not show this disc. Verbeek (1977) and in this study no specimens show this disc.

Genus: Lithraphidites Deflandre 1963

Type species: Lithraphidites carniolensis Deflandre 1963

Remarks:

This includes calcareous nannofossils with an elongate rod-shape with tapering ends. The rod is composed of four keels meeting at 90° along the axis of the rod. Each keel consists of two closely spaced

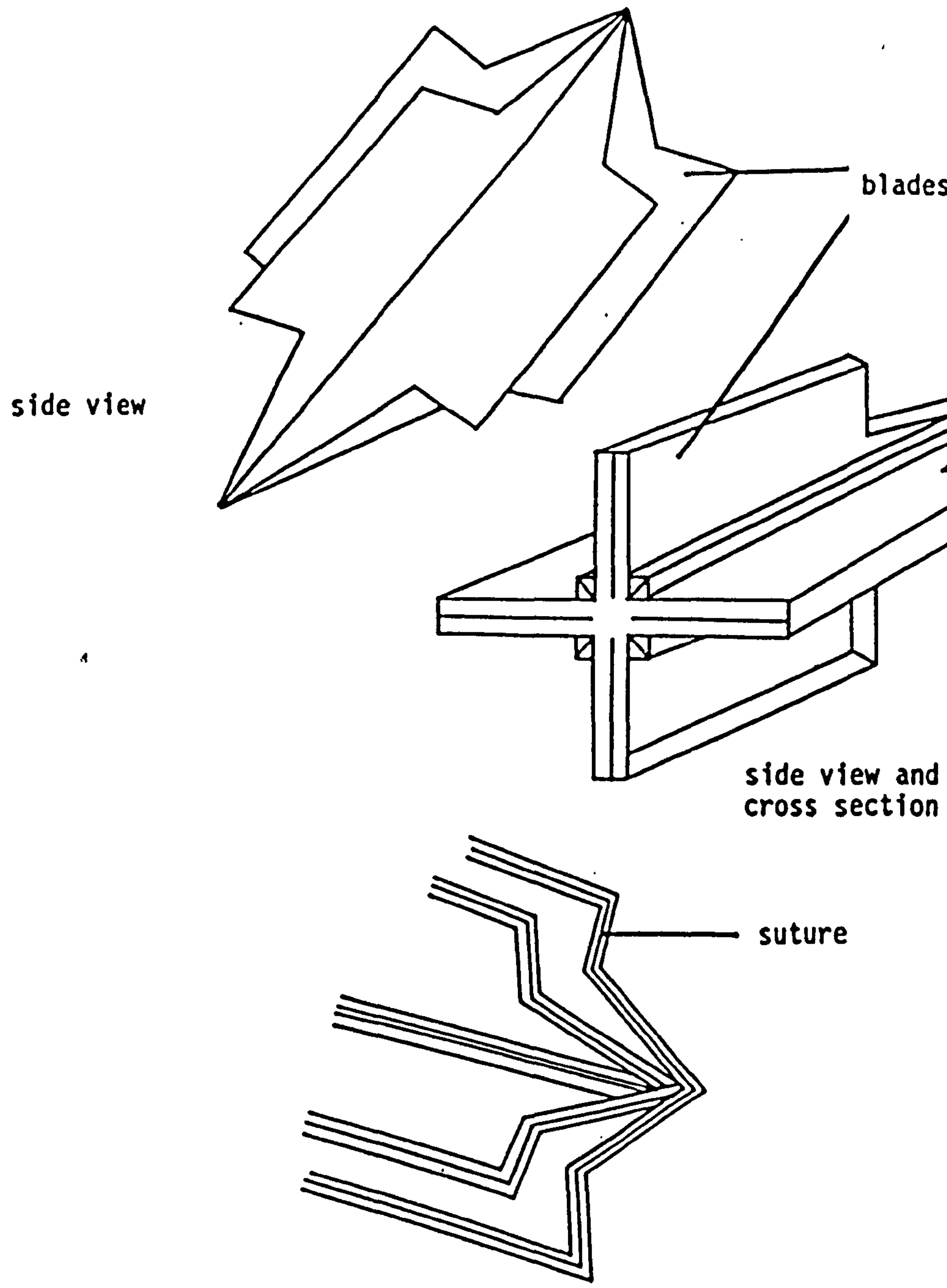


Fig.51 - Schematic drawings of the significant features of the genus Lithraphidites Deflandre 1963

blade-like elements. Two long narrow elements which are separated by long straight sutures are located between every two keels (Fig. 51).

Doeven (1983) has found a variety of forms of Lithraphidites in the Cenomanian, closely resembling the Maastrichtian L. quadratus. He considered them as Lithraphidites sp. aff. L. quadratus (p. 49, pl. 4, figs. 1-3). These forms were described by Crux (1982 p. 122, pl. 5.5, figs. 19 and 20) as Lithraphidites pseudoquadratus Crux 1981. Also Doeven observed two relatively short periods of radiation of Lithraphidites. The Cenomanian period with L. alatus, L. acutum and L. aff. quadratus (=L. pseudoquadratus Crux) and other variants. The Maastrichtian period with L. praequadratus, L. quadratus and L. grossopectinatus.

Lithraphidites carniolensis Deflandre

1963 Lithraphidites carniolensis Deflandre, p.3486, text-fig.1-10.

1977 Lithraphidites carniolensis Deflandre, Verbeek, p.99, pl.8, fig.4.

1978 Lithraphidites carniolensis Deflandre, Perch-Nielsen et al., pl. 5, fig.2.

1980 Lithraphidites carniolensis Deflandre, Hattner and Wise, p.64, pl.21, figs.2-4.

1982 Lithraphidites carniolensis Deflandre, Crux, pl.5.10, fig.1.

1983 Lithraphidites carniolensis Deflandre, Doeven, pl.6, figs.7-8.

Figured material:

Plate 4, fig.4. UCL-1919-21.Length: 8.5 µm (SEM)

Remarks:

Lithraphidites carniolensis is distinguished from the other *Lithraphidites* species by its narrow long keels with straight or smooth (not irregular) edges. The keels have a constant width at the middle and taper at the two ends of the rod forming a blunt end.

Occurrence:

This species has a worldwide geographic distribution throughout the Cretaceous. *Lithraphidites carniolensis* is observed in the Maastrictian sediments of Egypt.

Lithraphidites praequadratus Roth

1969 *Lithraphidites carniolensis* Deflandre, Bukry, p.66, partim, pl.39, fig.12, non pl.40, figs.1-2.

1978 *Lithraphidites praequadratus* Roth, p.749, pl.3, figs.1-4.

1980 *Lithraphidites praequadratus* Roth, Hattner and Wise, p.64, pl.21, figs.5-8, pl.41, figs.10-12.

Figured material:

Plate 4, fig.5. UCL-1919-17.Length: 9 µm (SEM)

Occurrence:

The short stratigraphic range of L. praequadratus makes it an important species within the Maastrichtian. This species was first described by Roth (1978, p. 740, 749) from the D.S.D.P. site 390 West of the Atlantic Ocean, North of Cuba. He also mentioned the stratigraphic range from Lower Maastrichtian to Middle Maastrichtian. Here this species first appeared in the A. cymbiformis Zone (Lower to Upper Maastrichtian) and continues through the L. quadratus Zone and the N. frequens Zone (Upper Maastrichtian) of Gebel Tarbouli, Gebel Duwi, Wadi Mellaha and Wadi Tarfa sections. Also it is found in the Upper Maastrichtian of Gebel Atshan and Gebel Um El Ghanayem.

Lithraphidites quadratus Bramlette and Martini

1964 Lithraphidites quadratus Bramlette and Martini, p.310, pl.6, figs.16-17, p.7, fig.8.

1977 Lithraphidites quadratus Bramlette and Martini, Verbeek, p.100, pl.8, fig.5.

1978 Lithraphidites quadratus Bramlette and Martini, Perch-Nielsen et al., pl.1, figs.56,57; pl.5, figs.3,4.

1980 Lithraphidites quadratus Bramlette and Martini, Hattner and Wise, p.64, pl.21, figs.9-12, pl.41, figs.6-9.

Figured material:

Plate 4, fig.6. UCL 1925-36 Length: 6.5 μm (SEM)

Remarks:

This species has keels with smooth (not irregular) edges, a constant width in the middle and tapers towards its two ends.

Occurrence:

The worldwide geographic distribution and abundance of *L. quadratus* within the Late Maastrichtian makes it an important zonal marker species. This species is recorded within the above mentioned time period in the studied area.

Lithraphidites grossopectinatus Bukry

1969 *Lithraphidites grossopectinatus* Bukry, p.66, pl.40, fig.3.

Figured material:

Plate 4, fig.7. UCL-2132-21 Length: 6.5 µm (SEM)
fig.8. UCL-2139-29 Length: 6 µm (SEM)

Remarks:

Lithraphidites grossopectinatus is distinguished from the other Maastrichtian *Lithraphidites* species by the presence of a few teeth which form on the outer margin of the keels. This species is doubtful and might be an etched *L. quadratus*. It does not show a constant shape for its tooth-like outline. The specimens investigated in this work represent variaties of forms with different shape of the outline. In all specimens the tooth-like margin does not extend to the ends of the central axis (as described by Bukry 1969). The presence of other species with irregular outline like *L. acutum* Verbeek and Manivit (1977) and *L. alatus* Thierstein (1972, in Roth and Thierstein 1972) makes me consider it.

Family: PODORHABDACEAE Noël 1965

Remarks:

In this family, the genera have margins which are constructed of two or three shields, and a central area occupied by bars or perforated plates. A stem may be present.

Genus: *Podorhabdus* Noël 1965

Type species: *Podorhabdus grassei* Noël 1965

Podorhabdus coronadventis (Reinhardt) Reinhardt

1966a *Cretarhabdus coronadventis* Reinhardt, p.26, pl.23, figs.29-30.

1970b *Podorhabdus coronadventis* (Reinhardt) Reinhardt, p.86.

1972 *Cretarhabdus coronadventis* Reinhardt, Roth and Thierstein, pl.5, figs.1-9.

Figured material:

Plate 4, fig.9. UCL-2135-18 Length: 10 µm (SEM) Broken specimen.

Occurrence:

This species has been recorded in Gebel Tarbouli section only. It is found in a few samples throughout the *A. cymiformis* Zone to the *N. frequens* Zone.

Podorhabdus decorus (Deflandre) Thierstein

1954 *Rhabdolithus decorus* Deflandre, in Deflandre and Fert, p.159, pl.13, fig.4-6, text-fig.87.

1972 Podorhabdus decorus (Deflandre) Thierstein, in Roth and Thierstein, p.437, pl.4, figs.7-8, 10-13.

Figured material:

Plate 4, fig.10. UCL-1872-9 Length: 9 µm (SEM)
fig.11. UCL-1872-10 Length: 11.7 µm (SEM)
fig.12. UCL-2135-9 Length: 6 µm (SEM)

Occurrence:

One of the commonest and longest-ranging species of the Cretaceous with a worldwide geographic distribution. Here, it is observed through the Maastrichtian of the studied areas (except Gebel Um El Ghanayem).

Genus: Cretarhabdus Bramlette and Martini 1964

Type species: Cretarhabdus conicus Bramlette and Martini 1964

Remarks:

In this genus the species have margins which are constructed of two shields. The distal shield is formed of two cycles, each made up of radial elements. The proximal shield is composed of one cycle of elements. The central area has cross bars which are more or less parallel to the short and the long axes of the ellipse. The cross bars divide the central area into four quadrants, each one has one or more (up to 3) lateral bars. The cross bars and the lateral bars may be bisected by more or less perpendicular bars to forming rings of small openings (up to 4 cycles of rings) around the centre of the central area. The major cross bars support a stem at their intersection.

Cretarhabdus conicus Bramlette and Martini

1964 Cretarhabus conicus Bramlette and Martini, p.299, pl.3, figs.5-8.

1968 Cretarhabus conicus Bramlette and Martini, Gartner, partim, p.21, pl.1, figs.10, 11, pl.3, figs.5a-c, 6a-c, pl.4, figs.9-12, pl.6, figs.3a-c, 4a-b(?), pl.11, figs.12a-c, pl.15, figs.9a-c, pl.16, figs.12, 13, pl.17, figs.10a-c, pl.20, figs.8,9, pl.22, figs.20,21, pl.24, figs.11a-c, pl.25, figs.3 (?), 4, non pl.14, figs.7-9, pl.16, fig.14.

1969 Cretarhabus conicus Bramlette and Martini, Bukry, p.35, pl.13, figs.7-12.

1971 Polypodorhabdus crenulatus (Bramlette and Martini), Perch-Nielsen, Shafik and Stradner, p.85, pl.12, figs.1,2, pl.13, figs.1-4.

1977 Cretarhabdus conicus Bramlette and Martini, Verbeek, p.101.

1982 Cretarhabus conicus Bramlette and Martini, Crux, pl.5.5, fig.7.

Figured material:

Plate 4, fig.13, UCL-1919-1 Length: 8 µm (SEM)

Description:

Cretarhabdus conicus is an elliptical to subcircular form with a narrow margin and large central area which is transversed by two cross bars more or less aligned with the major axes of the ellipse and more than one lateral bar (up to four lateral bars) in each quadrant of the central area. A long stem is present on the distal side of the intersection of the cross bars. The distal shield consists of a narrow outer cycle of elements and a broader inner one. The proximal shield is formed of one cycle of elongate elements.

Remarks:

In the LM/CP (by focusing up and down) the margin shows a broad bright cycle around the central area and a less bright, narrower outer cycle. Two extinction lines dividing the margin into four bright areas are present. The inner margin of the bright, broad inner cycle is crenulate (due to the overlapping of the central bars within the margin). The central area is dark and the bars are bright.

Cretarhabdus conicus differs from C. crenulatus by:

1) the margin of the former species is narrower that the margin of the latter species (compared to the diameter of the central area of each species).

2) in the central area of C. conicus there are two or more lateral bars in each quadrant while the lateral bars are up to two in each quadrant in the central area of the other species.

3) the central area has a cycle of small openings in C. conicus. This is absent in the central area of the other species.

4) the outline of the former species is elliptical to subcircular while its elliptical to elongate elliptical in the other one.

Occurrence:

Cretarhabdus conicus is a well known and common species throughout the Cretaceous marine deposits, on a worldwide geographic scale. Also it is recorded in the Maastrichtian of the studied areas (except Gebel Um El Ghanayem).

Cretarhabdus crenulatus Bramlette and Martini

1964 Cretarhabdus crenulatus Bramlette and Martini, p.300, pl.2, figs.21-24.

1966 Cocolithus actinosus Stover, p.138, pl.1, figs.15a-c, 16a-c, pl.8, fig.7.

1968 Cretarhabdus crenulatus Bramlette and Martini, Gartner, partim, p.22, pl.1, fig.9, pl.6, figs.6a-c, pl.19, figs.11a-d, pl.20, figs.10, 11, non pl.1, fig.8. (It is considered to be a transitional form between C. crenulatus and C. conicus because the margin is narrower than that of C. crenulatus).

1968 Cretarhabdus conicus Bramlette and Martini, Gartner, partim, p.21, pl.6, fig.4a-c(?), pl.25, fig.3(?), pl.14, figs.7,8,9 (?); pl.16, fig.14, non pl.1, figs.10,11, pl.3, figs.5,6, pl.4, figs.9-12, pl.6, figs.3a-c, pl.11, figs.12a-c, pl.15, figs.9a-d, pl.16, figs.12,12; pl.17, figs.10a-c, pl.20, fig.8, pl.22, figs.20, 21; pl.24, figs.11a-c, pl.25, fig.3.

1969 Cretarhabdus crenulatus crenulatus Bramlette and Martini, Bukry, p.35, pl.14, figs.1-6.

1975 Retacapsa crenulata (Bramlette and Martini) Grün, in Grün and Alleman, p.175, pliv, figs.4-6.

1977 Cretarhabdus crenulatus Bramlette and Martini, emend. Thierstein, Verbeek, p.101.

1980 Cretarhabdus crenulatus Bramlette and Martini, Hattner and Wise, p.61, pl.12, figs.2-5.

Figured material:

Plate 4, fig.14. UCL-1872-3 Length: 6 µm (SEM)

The figured specimen is typical of the morphotype called Cretarhabdus angustiforatus (Black 1971) Bukry 1973; this is believed to be a synonym of C. crenulatus but as the evolutionary origin of these forms earlier in the Cretaceous were not studied, no further comment is possible at present.

Description:

Elliptical to elongate elliptical form with a relatively broad margin and narrow central area which is spanned by two major cross bars more or less aligned with the short and long axes of the ellipse, supporting a crenulate central area.

Occurrence:

Cretarhabdus crenulatus is a worldwide geographically common species throughout the Cretaceous. Through this work, this species is observed to be more common in well preserved assemblages.

Cretarhabdus schizobrachiatus (Gartner) Bukry

1968 Vekshinella schizobrachiata Gartner, p.31 pl.13, figs.10,11; pl.20, fig.5.

1969 Cretarhabdus schizobrachiatus (Gartner) Bukry, p.36, pl.15, figs.4-6.

1977 Cretarhabdus schizobrachiatus (Gartner) Bukry, Verbeek, p.102.

1980 Cretarhabdus schizobrachiatus (Gartner) Bukry, Hattner and Wise, p.61, pl.12, figs.6-8.

Figured material:

Plate 4, fig.15. UCL-1872-29. Length: 7.5 μm (SEM)

Description:

Cretarhabdus schizobrachiatus is an elliptical form with a narrow margin and broad central area which is spanned by cross bars aligned with the major axes of the elliptical central area and supporting a long spine. The cross bars divide the central opening into four quadrants each one having two short lateral bars which branch from the cross bars. This arrangement of bars divide the central opening into alternating small and large openings.

Remarks:

This species differs from C. crenulatus by the position of the lateral bars which are close to the ends of the cross bars in the former species while they branch from the centre of the cross bars in the later species.

Occurrence:

This species was recorded from the Cretaceous by many authors (see the synonymy list). This species is found (from L. quadratus to N. frequens Zone) at Gebel Tarbouli and Wadi Mellaha sections, (from N. frequens to Q. trifidum Zone) at Wadi Tarfa and (from A. cymbiformis to L. quadratus Zone) at Gebel Duwi section.

Family: STEPHANOLITHIONACEAE Black 1968

Genus: Corollithion Stradner 1961

Type species: Corollithion exiguum Stradner 1961

Remarks:

The species have hexagonal, circular or elliptical outline with narrow margins composed of one or two cycles of elements. The large open central area is spanned by radial bars. Outer projections may be present.

Corollithion exiguum Stradner

1961 Corollithion exiguum Stradner, p.83, text-figs.58-61.

1963 Corollithion exiguum Stradner, Stradner, p.12 , pl.1, figs.12a-b.

1964 Corollithion exiguum Stradner, Bramlette and Martini, p.308, pl.5, figs.8-9.

1968 Corollithion exiguum Stradner, Gartner, p.35, pl.10, fig.26.

1968 Stephanlithion sp. aff. S. laffitei Noel, Gartner, p.35, pl.5, fig.14; pl.22, fig.18.

1969 Corollithion exiguum Stradner, Bukry, p.40, pl.18, fig.12, pl.19, fig.1.

1971 Corollithion exiguum Stradner, Shafik and Stradner, p.81, pl.46, figs.1-4, pl.47, fig.1.

1980 Corollithion exiguum Stradner, Hattner and Wise, p.60, pl.9, figs.6-9.

Figured material:

Plate 5, fig.1. UCL-2135-19. Length: 3.5 µm (SEM)

Description:

A very distinctive form with a thin hexagonal margin and large open central area which is spanned by six bars radiating from the centre. A small central process is present.

Remarks:

The specimens belonging to this species are variable in outline. Some have hexagonal shapes with two longer or shorter opposite sides and the other four are equal. Others show six equal sides. Some specimens show small outer projections which extend outwards of the margin. This was also observed in specimens which were illustrated by Bukry (1969) and Shafik and Stradner (1971) (see the synonomy list).

Occurrence:

Corollithion exiguum has been reported to have a worldwide geographic occurrence throughout the Late Cretaceous (see synonomy). Throughout this work, this species is found in few of the Maastrichtian samples at Gebel Tarbouli, Wadi Mellaha, Gebel Duwi.

Corollithion rhombicum (Stradner and Adamiker) Bukry

1966 Zygolithus rhombicus Stradner and Adamiker, p.339, pl.2, fig.1, text-figs.5-7.

1969 Corollithion rhombicum (Stradner and Adamiker) Bukry, p.41, pl.19, figs.2-4.

1980 Corollithion rhombicum (Stradner and Adamiker) Bukry, Hattner and Wise, p.60, pl.10, figs.2-5.

Description:

Small delicate species with rhombic outline. The central area has a long central bar aligned with the long diagonal axis of the margin and dividing the open central area into two openings, each having four or five short bars. A central stem is present.

Occurrence:

This species is generally rare on a worldwide scale within the Cretaceous, possibly due to its delicate construction which easily dissolves or breaks off. Corollithion rhombicum is found in few of the Maastrichtian samples at Wadi Mellaha section, Gebel Duwi, Gebel Tarbouli and Gebel Atshan.

Corollithion? madagaskarensis Perch-Nielsen

1973 Corollithion? madagaskarensis Perch-Nielsen, p.311, pl.2, figs.9,12, 15, 17, pl.10, figs.6-7.

1978 Prediscosphaera cf. P. honjoi Bukry, Perch-Nielsen et al., pl.3, fig.8.

1979 Corollithion? madagaskarensis Perch-Nielsen, p.256, fig.24 (diagram).

Figured material:

Plate 5, fig.2. UCL-2135-22.Length: + 3 µm (SEM)
fig.3. UCL-2135-28.Length: + 2 µm (SEM)

Occurrence:

This species was described by Perch-Nielsen (1973, p. 311) from the Maastrichtian, L. quadratus Zone at Majunga basin, Madagascar. According to Perch-Nielsen (1979a, p. 256) this species is only found in the Maastrichtian. In Egypt, C.? madagaskarensis is recorded within the A. cymbiformis Zone, Gebel Tarbouli section sample Number 20 only.

Genus: Stephanolithion Deflandre 1939

Type species: Stephanolithion bigoti Deflandre 1939

Remarks:

This genus differs from genus Corollithion Stradner (1961) in possessing outer radial spines or projections.

Stephanolithion laffittei Noël

1956 Stephanolithion laffittei Noël, p. 318, pl.2, figs.5-6.

non 1968 Stephanolithion sp. aff. S. laffitei Noël, Gartner (error for laffittei), p.35, pl.5, fig.14, pl.22, fig.18.

1969 Stephanolithion laffittei Noël, Čepek and Hay, p.326, text-fig.2, no.12.

1969 Stephanolithion laffittei Noël, Bukry, p.43, pl.21, figs.7-11.

1971 Stephanolithion laffitei Noël, Shafik and Stradner (error for laffittei), p.89, pl.47, fig.2.

1975 Stephanolithion laffittei Noël, Grün and Allemann, p.187, pl.7, fig.4, text-fig.26.

1975 Stephanolithion caravacaensis Grün, Grün and Allemann, p.188, pl.7, figs.1-3, text-fig.27.

1978 Stephanolithion laffittei Noël, Roth, p.743, pl.1, figs.10a-b.

1980 Stephanolithion laffittei Noel, Hattner and Wise, p.67, pl.31, figs.1-6.

Figured material:

Plate 5, fig.4. UCL-2130-27 Diameter: 3.5 μm (SEM)

Remarks:

The margin of Stephanolithion laffittei consists of two cycles, a long outer cycle and a short inner one extending around the central radial bars.

Stephanolithion laffittei is distinguished from C. exiguum by its higher circular margin and the presence of long lateral processes.

Grun (1975) described new species, S. caravacaensis and mentioned that this species differed from S. laffittei by its conical outline. The SEM photographs of Grun (pl. 7, figs. 1-3) are heavily overgrown. Also the outline of S. laffittei is slightly conical.

Occurrence:

Stephanolithion laffittei has been reported by many authors (see synonymy list) within the Late Jurassic and Cretaceous. This species is found most commonly in well preserved assemblages in the studied sections.

Genus: Stoverius Perch-Nielsen 1986

type species: Stoverius achylosus (Stover 1966) Perch-Nielsen 1986

Stoverius biarcus (Bukry) Perch-Nielsen

1969 Cylindralithus biarcus Bukry, p.42, pl.20, figs.1-3.

1977 Cylindralithus biarcus Bukry, Verbeek, p.111.

1980 Cylindralithus biarcus Bukry, Hattner and Wise, p.62, pl.15, figs.4-9, pl.16, figs.1-2.

1982 Cylindralithus biarcus Bukry, Crux, pl.5.3, fig.16, pl.5.9, fig.13.

1986 Stoverius biarcus (Bukry) Perch-Nielsen, p.839.

Figured material:

Plate 5, fig.6. UCL-1870-11. Diameter: 5.5 μm (SEM)
fig.5. UCL-2135-4. Diameter: 4.5 μm (SEM)
Plate 12, fig.14. UCL-1861-16. Diameter: 5.9 μM (LM)

Remarks:

In this species the central opening has two cross bars and a thin cycle of small elements around the cross bars. The number of elements which form the cylinder wall is 16 to 28.

Stoverius biarcus differs from *S. coronatus* Bukry (1969) by:

1) the cross bars of the central area of the former species are broader than the cross bars of the latter species.

2) the cross bars of *S. biarcus* are curved and form 2 large and 2 small openings in the central area while in the other species the cross bars are straight, more or less perpendicular on each other and form four openings of about the same dimensions.

Genus: *Cylindralithus* Bramlette and Martini 1964

Type species: *Cylindralithus serratus* Bramlette and Martini 1964

Cylindralithus duplex Perch-Nielsen

1973 *Cylindralithus duplex* Perch-Nielsen, p.314, pl.5, figs.3,5, pl.10, figs.29,30.

1977 *Cylindralithus serratus* Bramlette and Martini, Verbeek, p.111, partim, pl.10, figs.5-6, 8-9; non pl.10, fig.7.

1979 *Cylindralithus duplex* Perch-Nielsen, Perch-Nielsen, p.256, fig.24.

Figured material:

Plate 5. fig.7. UCL-1872-19. Diameter: 4 µm (SEM)
Plate 12. fig.13. UCL-2283-5. Diameter: 4.9 µm (LM)

Remarks:

Cylindralithus duplex is distinguished from C. crassus and C. serratus by its blocky, irregularly spaced elements of the proximal side and the presence of two cycles of elements which surround the central area, the outer is broad and the inner is narrow.

Perch-Nielsen (1979a, p. 256, fig. 24) represented two diagrams for C. duplex one of which shows the side view with the same degree of flaring towards the distal and proximal sides. In our material variations in the shape of the cylinder are observed in side view. Specimens slightly flaring towards the proximal side and slightly tapering towards the distal side, specimens flaring towards proximal side and strongly flaring towards the distal side, and specimens flaring proximally and distally with the same degree.

Cylindralithus oweinae Perch-Nielsen

1973 Cylindralithus oweinae Perch-Nielsen, p.314, pl.4, figs.7-8. pl.5, fig.1.

1978 Cylindralithus oweinae Perch-Nielsen Perch-Nielsen et. al. pl.1, figs. 68-71, pl. 6, figs. 1-5.

1980 Cribrocorona gallica (Stradner) Perch-Nielsen, Hattner and Wise, p.61, partim, pl.13, figs.5-6,8-9, pl.14, fig.1, non pl.13, fig.7.

Figured material:

Plate 5, fig.8. UCL-2132-26.Diameter: 6 μm (SEM)
Plate 12, fig.11. UCL-2281-35.Diameter: 5.9 μm (LM)

Remarks:

This species is subspherical slightly tapering from the proximal and distal sides with three or four rings of nodes decorating the surface.

Cylindralithus oweinae Perch-Nielsen differs from *Cribrocorona gallica* (Stradner) Perch-Nielsen by:

1) the central area of the former species is open while there is a perforated plate in the central area of the latter one.

2) *Cylindralithus oweinae* is subspherical, slightly tapering distally and proximally while the other one is cylindrical in shape.

3) the rings of nodes which decorate the outer surface of the former species are greater in number than those of the latter species.

Occurrence:

This species was described by Perch-Nielsen *et al.* (1973, p. 314) from the *N. frequens* Zone (Upper Maastrichtian) at Gebel Oweina, near Luxor, Egypt. During this study *C. oweinae* is commonly found through out the *A. cymbiformis* Zone, the *L. quadratus* Zone and *N. frequens* at Wadi Mellaha section. It is also observed in *L. quadratus* Zone and the *A. cymbiformis* Zone of Gebel Duwi and in *L. quadratus* Zone and *N. frequens* Zone of Gebel Atshan section. Also in the *N. frequens* Zone at Gebel Tarbouli.

Cylindralithus nudus Bukry

1969 *Cylindralithus nudus* Bukry, p.43, pl.20, figs.7-8.

Figured material:

Plate 5, fig.9. UCL-2139-7. Long diameter: 5 µm (SEM)
Plate 12, fig.10. UCL-2281-24.Long diameter: 3.9 µm (LM)

Occurrence:

This species is found in the N. frequens Zone (Upper Maastrichtian) at Gebel Tarbouli(sample number 52)and Wadi Mellaha sections.

Cylindralithus sp.1

Figured material:

Plate 12, fig.12. UCL-2281-33.Diameter: 5.9 µm (LM)

Remarks:

The wall of this species has a more or less constant diameter. It is flaring towards one end outwards. The outer surface is decorated by one or more cycles of nodes.

Occurrence:

This species is observed in the Maastrichtian(Nephrolithus frequens Zone) of Wadi Mellaha and Gebel Tarbouli .

Cylindralithus serratus Bramlette and Martini

1964 Cylindralithus serratus Bramlette and Martini, p.310, pl.5, figs.18-20.

1969 Cylindralithus serratus Bramlette and Martini, Bukry, p.43, pl.20, figs. 11-12.

Figured material:

Plate 5, fig.10. UCL-2152-15.Diameter: 5.5 µm (SEM)

Occurrence:

This is well documented throughout the Upper Cretaceous on a worldwide scale. This species is found in the studied sections throughout the Maastrichtian samples (except Gebel Um El Ghanayem).

Genus: Cribrocorona Perch-Nielsen 1973

Type species: Coccolithus gallicus Stradner 1963

Cribrocorona gallica (Stradner) Perch-Nielsen

1963 Coccolithus gallicus Stradner, p.10, pl.1, fig.8-8a.

1964 Cylindralithus? gallicus (Stradner), Bramlette and Martini, p.308, pl.5, figs.15-17.

1973 Cribrocorona gallica (Stradner) Perch-Nielsen, p.312, pl.4, figs.1-4, pl.10, figs.25-28.

1977 Cribrocorona gallica (Stradner) Perch-Nielsen, Verbeek, p.103, pl.8, figs.10-12.

Figured material:

Plate 5, fig.11. UCL-1925-31.Diameter: 6 µm (SEM)

Occurrence:

This species is found in the L. quadratus Zone and the N. frequens Zone at Gebel Tarbouli, Gebel Atshan, and Wadi Mellaha sections in the A. cymbiformis Zone and L. quadratus Zone at Gebel Duwi.

Family: POLYCYCLOLITHACEAE Forchheimer 1972

Genus: *Lithastrinus* Stradner 1962

Type species: *Lithastrinus grilli* Stradner 1962

Remarks:

This genus includes short cylindrical forms composed of long elements flaring at one or both ends. The central area is occupied by a radial diagonal element forming a plate.

The species belong to this genus are distinguished from those of genus *Cylindralithus* by the shorter cylindrical body, less and longer elements of the margin and the presence of a plate in the central area.

Lithastrinus sp. A.

Description:

This is a cubic form with concave faces and corners which are extended to form 8 arms protruding outwards.

Figured Material:

Plate 5, fig. 12, UCL-1865-13

Remarks:

Lithastrinus sp. A. differs from *L. grilli* by its less number of arms (the number of arms of *L. grilli* from 5 to 7 at each end), also the central part has the shape of a cube.

Occurrence:

This species is rare in the Q. trifidum Zone at Gebel Tarbouli section.

Genus: Micula Vekshina 1959

Type species: Micula staurophora (Gardet 1955) Stradner 1963

Micula concava (Stradner) Bukry

1960 Nannotetraster concava Stradner, Martini and Stradner, p.269, figs.18a-d.

1963 Micula staurophora (Gardet) Stradner, partim, p.14, pl.4, figs.12b-c, non pl.4, fig.12a.

1968 Micula decussata Vekshina, Gartner, p.47, partim, pl.2, figs.6-7, pl.9, figs.18-20, pl.14, fig.14, non pl.2, figs.5?, 8?, pl.4, fig.18?, pl.14, fig.13?, pl.18, fig.7, pl.20, fig.15?

1969 Micula decussata concava (Stradner) Bukry, p.67, pl.40, figs.7-8.

1977 Micula concava (Stradner) Bukry, Verbeek, p.119, pl.11, fig.11.

1978 Micula staurophora (Gardet) Stradner, Perch-Nielsen et al., partim, pl.1, figs.45, 47, pl.7, figs.2, 4-5, 7-8, 10, non pl.1, fig.46, pl.7, fig.1.

1980 Micula decussata Vekshina, Hattner and Wise, p.65, pl.26, figs.6-9.

Figured material:

Plate 5, fig.14. UCL-2133-5.Length of edge: 7 μm (SEM)

Remarks:

This species is distinguished from M. staurophora by the presence of long processes at the corners, more depressed edges and more concave faces.

Some authors have considered M. concava as synonomus to M. staurophora and others have considered them as two separate species. This is discussed by Bukry (1969), Verbeek (1977), Roth (1978), Hattner and Wise (1980). Verbeek (1977, p. 119) shows that M. concava first appeared in younger sediments than to M. staurophora. Some of Gartner's photographed specimens (1968) are very poorly preserved and doubtful (see synonymy list).

Micula staurophora (Gardet) Stradner

1955 Discoaster staurophora Gardet, p.543, pl.10, fig.96.

1959 Micula decussata Vekshina, p.71, pl.1, fig.6, pl.2, fig.11.

1963 Micula staurophora (Gardet) Stradner, partim, p.14, pl.4, fig. 12a, non pl.4, fig.12b-c.

1969 Micula decussata decussata Vekshina, Bukry, p.67, pl.40, figs. 5-6.

1978 Micula staurophora (Gardet) Stradner, Perch-Nielsen et al. partim., pl.1, fig.46, pl.7, fig.1, non pl,1, figs.45, 47, pl. figs.2, 4-5, 7-8, 10 .

Occurrence:

This is a very common species in the Upper Cretaceous (Coniacian to Maastrichtian) sediments. It was recorded by many authors from different areas in the world throughout its stratigraphic range. The presence of this species in the Danian (Early Palaeocene) is usually considered as natural contamination (reworking). Romein (1979, p. 25, 35, 98, 184) has extended the stratigraphic range of M. decussata (=M. staurophora) to the N. fulgens Zone (Middle Eocene) after investigating the Caravaca section (S.E. Spain) and Nahal Avdet section (Israel). In this work M. staurophora is consistently present in the Maastrichtian samples of the studied sections, it is also detected rarely in the early samples of the Danian of Wadi Mellaha, Gebel Atshan and Gebel Um El Ghanayem which is considered to be reworked .

Micula sp.

Figured material:

Plate 5, fig.15. UCL 2152-6.Length of edge:+2.5 µm (SEM)

Remarks:

This species is formed of 8 elements. Four elements have more or less the same size and shape, occupying the convex side and extending into the sides of the cube. The other four elements are slightly larger and extend underneath the smaller ones. This species is distinguished from M. murus by its cubic shape and the shorter elements on the concava side.

Occurrence:

This species is recorded in the N. frequens Zone of Wadi Tarfa section.

Micula murus (Martini) Bukry

1961 Tetralithus murus Martini, p.4, pl.1, fig.6, pl.4, fig.42.

1964 Tetralithus murus Martini, Bramlette and Martini, p.320, pl.6, figs.18-21.

1973 Micula mura (Martini) Bukry, p.679.

1979a Micula murus (Martini) Bukry, Perch-Nielsen, pl.1, fig.12.

Figured material:

Plate 6, fig.1. UCL-2152-26.

Occurrence:

This is an important species stratigraphically as it is the zonal marker of the Upper Maastrichtian in many areas in the world (tropical and subtropical areas). Micula murus is known to be more common towards the equator. This species is found rare in the Nephrolithus frequens Zone of the studied sections due to the poor preservation.

Micula prinsii Perch-Nielsen

1979a Micula prinsii Perch-Nielsen, p.266, pl.1, figs.11, 14-16.

Figured material:

Plate 6, fig.2. UCL-1934-14. Length = 7.5 μm (SEM)
fig.3. UCL-1934-2. Length = 8 μm (SEM)
Plate 12, fig.5. UCL-2278-9. Length = 6.8 μm (LM)

Remarks:

Micula prinsii is distinguished from M. murus by its longer elements which have bifurcate ends.

Occurrence:

This species is vertically restricted to the Upper Maastrichtian. It is found rare in the Upper Maastrichtian (N. frequens Zone) of Gebel Duwi, Wadi Tarfa and Wadi Mellaha sections. Micula prinsii is always more common in well preserved assemblages than in poorly preserved ones.

Genus: Quadrum Prins and Perch-Nielsen 1977

Type species: Quadrum gartneri Prins and Perch-Nielsen 1977

Remarks:

The species which belong to this genus are composed of one or two layers of three or four outward radiating calcite elements. The Cretaceous forms assigned to genus Tetralithus Gardet have been re-assigned to the well defined genera Calculites, Quadrum and Ceratolithoides.

Hattner and Wise (1980) produced a new genus Uniplanarius to replace genus Quadrum Prins and Perch-Nielsen, as the type species of the latter genus has been considered a morphotype of Micula staurophora (Roth and Bowdler 1979, p.275). This is not followed here as both species have a different construction.

Quadrum gartneri Prins and Perch-Nielsen

1968 Tetralithus gothicus Deflandre, Gartner, p.42, pl.24, figs.4a-d.

1974 Micula staurophora (Gardet) Stradner, Thierstein, partim, pl.12, figs.4-8, non pl.12, figs.1-3, 9-11.

1976 Tetralithus pyramides Gardet, Verbeek, pl.1, figs.4,6.

1977 Quadrum gartneri Prins and Perch-Nielsen , in Manivit et al., p.177, pl.1, figs.9-10.

1982 Quadrum gartneri Prins and Perch-Nielsen, Crux, pl.5.7, figs.8 - 10, pl.5.10, fig.19.

Figured material:

Plate 6, fig.4. UCL-2142-11. Diameter: 6.5 μm (SEM)

Remarks:

Crux (1982) split Q. gartneri into two subspecies. The older form (subspecies-1) ranges from Turonian to Santonian with elements arranged orthogonally and the younger form (subspecies 2) ranges from Coniacian to Maastrichtian with slightly off set and elongate elements. The specimens detected in the Maastrichtian of Egypt fit his Q. gartneri subspecies 2. But the poor preservation and the presence of the very rare specimens found make it difficult to conform to this through our Cretaceous samples.

Quadrum gothicum (Deflandre) Prins and Perch-Nielsen

1959 Tetralithus gothicus Deflandre, p. 138, pl.3, fig.25.

1961 Tetralithus gothicus Deflandre, Stradner and Papp, p.124, pl.40, fig.13a-b, text fig.13/2.

1977 Quadrum gothicum (Deflandre) Prins and Perch-Nielsen, in Manivit et al., p.178.

1977 Quadrum gothicum (Deflandre) Prins and Perch-Nielsen, Verbeek, p.122, pl.12, fig.10.

non 1980 Uniplanarius gothicus (Deflandre) Hattner and Wise, p.68, pl.32, fig.4, pl.42, figs.4-5.

Figured material:

Plate 12, fig.16. UCL-1861-4. Diameter: 5.9 µm (LM)

Remarks:

This species has shorter arms than those of Q. sissinghii. Hattner and Wise (1980) have considered Q. nitidum (equal to Q. sissinghii, this work) to be a junior synonym to Q. gothicum and changed the generic name to Uniplanarius. The stratigraphic range of both species is different by some authors Verbeek (1977, p. 30, 122), Perch-Nielsen (1979a, p. 245).

Quadrum sissinghii Perch-Nielsen

non 1961 Tetralithus nitidus Martini, p.4, pl.1, fig.5, pl.4, fig.41.

1977 Quadrum nitidum (Martini) Prins and Perch-Nielsen, in Manivit et al., p.178.

1980 Uniplanarius gothicus (Deflandre) Hattner and Wise, p.68, pl.32, fig.4, pl.42, figs.4-5.

1986 Quadrum sissinghii Perch-Nielsen, p.838, pl.3, figs. 3-5.

Figured material:

Plate 12, fig.17. UCL-1856-28.Diameter: 9.8 µm (LM).

Remarks:

Perch-Nielsen (1986) gave the name Q. sissinghii to the Late Cretaceous forms previously known as Q. nitidum, after Aubry (1983, p.149) has shown that Q. nitidum Martini (1961) is a form restricted to the Eocene .

Occurrence:

This is an important marker species as the disappearance (the extinction level) of this species marks the top of the Q. trifidum Zone (Late Campanian to Early Maastrichtian). Quadrum sissinghii is found in the Zone at Gebel Tarbouli and Wadi Tarfa sections.

Quadrum trifidum (Stradner) Prins and Perch-Nielsen

1961 Tetralithus gothicus trifidus Stradner , in Stradner and Papp, p.124, text-fig.23/3.

1968 Tetralithus nitidus Martini, Gartner, p.42, partim, pl.9, fig.14, pl.13, figs.4a-c, non pl.13, figs.3a-c.

1977 Quadrum trifidum (Stradner) Prins and Perch-Nielsen , in Manivit et al., p.178.

1980 Uniplanarius trifidus (Stradner) Hattner and Wise, p.68, pl.32, figs.5-6, pl.42, figs.6-8.

Figured material:

Plate 6, fig. 5. UCL-2136-18. Diameter: 9.5 µm (SEM)
Plate 12, fig.15. UCL-1861-6. Diameter: 11.7 µm (LM)

Remarks:

Two forms of Q. trifidum are observed in my sections one with three elongate arms and the other with three short arms. Roth (1973) mentioned that the short-armed forms are more common in open-ocean sediments. In the present project both forms are common.

Occurrence:

The marker species of the Q. trifidum Zone (Late Campanian-Early Maastrichtian). The extinction level of this species marks the upper boundary of the above mentioned zone. This species is recorded throughout the zone at Gebel Tarbouli and Wadi Tarfa sections.

Genus Rucinolithus Stover 1966

Type species: Rucinolithus hayi Stover 1966

Rucinolithus hayi Stover

1966 Rucinolithus hayi Stover, p.156, pl.7, fig.21, pl. 9, fig. 22.

1977 Rucinolithus hayii Stover, Verbeek, p.123, pl.12, fig.13.

Figured material:

Plate 6, fig.6. UCL-2136-3.Diameter: 11 μm (SEM)

Occurrence:

This species was recorded by Verbeek (1977, p. 17, 23, 25) from El Kef section (Tunisia) and El Burrueco section (Southern Spain) from the Santonian to the Campanian (Q. trifidum Zone). In Egypt, during this work R. hayi is very rare only in the lowest samples of Gebel Tarbouli which are dated as Late Campanian-Early Maastrichtian.

Family: THORACOSPHAERACEAE Schiller 1930

Genus: Thoracosphaera Kamptner 1927

Type species: Syracosphaera heimi Lohmann 1920

Remarks:

Thoracosphaera has recently been known as a calcareous dinoflagellate. This is discussed by Romein (1979), Perch-Nielsen (1985, p. 524). The genus Thoracosphaera includes forms with hollow globular or oval calcareous bodies with small opening closed by an operculum. These forms are built up of tiny calcareous elements. In the light microscope, cross-polarised light, every calcite element behaves independently giving a pattern of alternate dark and bright areas.

Thoracosphaera operculata Bramlette and Martini

1964 Thoracosphaera operculata Bramlette and Martini, p.305, pl.5, figs.3-7.

1977 Thoracosphaera operculata Bramlette and Martini, Verbeek, p.113, pl.10, fig.11.

1979 Thoracosphaera operculata Bramlette and Martini, Romein, p.182, pl.1, fig.1.

1980 Thoracosphaera operculata Bramlette and Martini, Hattner and Wise, p.67, pl.31, fig.3.

Figured material:

Plate 6, fig.7. UCL-2053-24.Diameter of the sphere: 16.6 μm (SEM)

Remarks:

This species is distinguished from T. saxea by its smaller elements.

Occurrence:

Thoracosphaera operculata is one of the species which has survived the Cretaceous-Tertiary boundary event. This species is reported by Bramlette and Martini (1964, p. 306) as common in the type Danian and its equivalents in southwestern France, Tunisia and Alabama (Clayton Formation). Also they mentioned the presence of rare specimens in the Maastrichtian from Tunisia and Alabama, and in the Palaeocene (Thanetian) strata from the basal Lodo Formation of California. Verbeek (1977, p. 25) has recorded this species from the El Kef section, Tunisia from the Maastrichtian (L. quadrtus Zone and M. murus Zone) to the Danian (NP1 and NP2). Romein (1979, p. 50) has marked the Cretaceous-Tertiary boundary by the massive occurrence or increased frequency of Braarudosphaera bigelowi and/or T. operculata. During this study T. operculata is found in the Maastrichtian (A. cymbiformis Zone, L. quadratus, N. frequens Zones) of Wadi Mellaha section. In the same section the species becomes more common throughout the Palaeocene. In Wadi Tarfa this species is rare at the top sample of the Upper Maastrichtian and more common throughout the Lower Tertiary. It is also recorded from Gebel Duwi (N. frequens Zone-NP7/8), Gebel Atshan (NP3-NP10) and Gebel Tarbouli (NP10). It is found in the Maastrichtiar and the Palaeocene of Gebel Um El Ghanayem.

Thoracosphaera saxea Stradner

1961 Thoracosphaera saxea Stradner, p.84, text-fig.71.

1967 Thoracosphaera saxea Stradner, Hay and Mohler, p.1534, pl.203, fig.5.

1979 Thoracosphaera saxea Stradner, Okada and Thierstein, pl.8, fig.7; pl.19, fig.12.

1981 Thoracosphaera saxea Stradner, Haq and Aubry, pl.3, fig.9.

Occurrence:

This species is recorded throughout the Early Tertiary from the studied areas during this work. It is also observed in the Maastrichtian strata (as T. operculata) but it is more common within the above mentioned time period. It is recorded from Gebel Duwi (N. frequens Zone and NP3), Gebel Atshan (NP3-NP9), Gebel Um El Ghanayem (NP4-NP9), and Wadi Tarfa (NP3-NP10).

Family: PREDISCOSPHAERACEAE Rood, Hay and Barnard 1971

Genus: Prediscosphaera Vekshina 1959

Type species: Prediscosphaera decorata Vekshina 1959

Remarks:

Genus Prediscosphaera is the only genus of the family PREDISCOSPHAERACEAE. The species belonging to this genus have a margin constructed of two shields. Each shield is formed of sixteen wedge-shaped non-imbricate elements. The central area is opened and occupied by x-shaped or, + - shaped cross bars.

Prediscosphaera cretacea (Arkhangelsky) Gartner sub. sp. cretacea Reinhardt

1912 Coccolithophara cretacea Arkhangelsky, p.410, pl.6, figs.12,13.

1966a Deflandrius cretaceus cretaceus (Arkhangelsky) Reinhardt, p.35, pl.15, fig.4; non pl.10, figs, 1a-b, 2a; text-figs.14a-b.

1968 Prediscosphaera cretacea (Arkhangelsky) Gartner, p.19, partim, pl.2, figs.10-14, pl.3, figs.8a-c, pl.4, figs.19-24, pl.6, figs.14-15, pl.9, figs.1-4, pl.12, fig.1, pl.14, figs.20-22, pl.18, fig.8, pl.22, figs.1-3, pl.23, figs.4, pl.25, figs.12-14, pl.26, figs.2a-c, non pl.23, figs.5-6.

1969 Prediscosphaera cretacea cretacea (Arkhangelsky) Gartner, Bukry p.38, pl.16, fig.12; pl.17, figs.1-6.

1978 Prediscosphaera cretacea (Arkhangelsky) Gartner, Perch-Nielsen, et al., pl.1, figs.37, 38; pl.3, figs.1-7.

1980 Prediscosphaera cretacea (Arkhangelsky) Gartner, Hattner and Wise, p.66, pl.28, figs.4-9, pl.29, figs.1,2.

1982 Prediscosphaera cretacea (Arkhangelsky) Gartner cretacea, Crux, pl.5.8, fig.6, pl.5.5, figs.9-10.

Figured material:

Plate 6, fig.8. UCL-2131-17. Diameter: 5 μm (SEM).

Remarks:

Many species and subspecies with minor differences were included under P. cretacea by authors such as Verbeek (1977), Hattner and Wise (1980), Smith (1981) and other authors have considered these minor ultrastructural differenaces as did Bukry (1969), Perch-Nielsen (1979a), and Crux (1982). The later authors are followed as Perch-Nielsen (1979, p. 254) shows the stratigraphic distribution chart of species of Prediscosphaera and their stratigraphic importance.

Occurrence:

This species has a well documented worldwide occurrence throughout the Upper Cretaceous. This is one of the dominant species throughout the Maastrichtian of the studied sections.

Prediscosphaera cretacea lata Bukry

1969 Prediscosphaera cretacea lata Bukry, p.39, pl.17, figs.7-9.

Figured material:

Plate 6, fig.9. UCL-2142-32. Diameter: 5 μm (SEM)

Remarks:

This species is distinguished by the very broad inner cycle.

Prediscosphaera spinosa (Bramlette and Martini) Gartner

1964 *Deflandrius spinosus* Bramlette and Martini, p.301, pl.2, figs.17-20.

1968 *Prediscosphaera spinosa* (Bramlette and Martini) Gartner, p.20; pl.2, figs.15-16; pl.3, figs.9a-b, 10a-b, pl.5, figs.7-9, pl.6, figs.16a-d; pl.11, figs.17a-c.

1969 *Prediscosphaera spinosa* (Bramlette and Martini) Gartner, Bukry, p.40, pl.18, figs.7-9.

1980 *Prediscosphaera spinosa* (Bramlette and Martini) Gartner, Hattner and Wise, p.66, pl.29, figs.3-6.

Figured material:

Plate 6, fig.10. UCL-2131-7. Length: 3 μm (SEM)

Occurrence:

This species has a worldwide distrubtion within the late Cretaceous period. It has been reported by many authors (see synonymy list) from different localities. This species is recorded in the studied sections from Egypt throughout the Maastrichtian (except Gebel Um El Ghanayem).

Prediscosphaera honjoi Bukry

1969 *Prediscosphaera honjoi* Bukry, p.39, pl.18, figs.4-6.

1977 *Prediscosphaera quadripunctata* (Górka) Verbeek, p.109, pl.10, fig.3.

1978 Prediscosphaera bukryi Perch-Nielsen, Perch-Nielsen et al., pl.3, figs.10-11.

1978 Prediscosphaera honjoi Bukry, Perch-Nielsen et al.,pl.1, figs.41.42.

Figured material:

Plate 6, fig.11. UCL-2142-3.Length: 3 μm (SEM)

Occurrence:

This species is recorded in the Upper Maastrichtian of Wadi Tarfa Section.

Prediscosphaera stoveri (Perch-Nielsen) Shafik and Stradner

1968 Deflandrius stoveri Perch-Nielsen, p.66, pl.16, fig.13.

1969 Prediscosphaera germanica Bukry, p.39, pl.18, figs.1-3.

1971 Prediscosphaera stoveri (Perch-Nielsen) Shafik and Stradner, p.88, pl.22, fig.1.

1978 Prediscosphaera stoveri (Perch-Nielsen) Shafik and Stradner, Perch-Nielsen et al., pl.1, figs.39-40, pl.3, fig.12.

1982 Prediscosphaera stoveri (Perch-Nielsen) Shafik and Stradner, Crux, pl.5.8, figs. 9-10, pl.5.5, figs.12,16.

Figured material:

Plate 6, fig.12. UCL-1925-17. Diameter: 3.5 μm (SEM)

Occurrence:

Crux (1982, p. 95, 107, 109) has considered the first occurrence of P. stoveri to mark the lower boundary of the Prediscosphaera stoveri Zone Crux (1982) of (Upper) Campanian age in different localities in southeast England and France. During this work P. stoveri is found in the Maastrichtian strata of the studied areas. It is recorded from Gebel Tarbouli (Q. trifidum Zone-N. frequens Zone), Wadi Mellaha (A. cymbiformis Zone-N. frequens Zone), Wadi Tarfa (Q. trifidum Zone-A. cymbiformis Zone) and Gebel Duwi (A. cymbiformis Zone-L. quadratus Zone).

Family: CALYPTROSPHAERACEAE Boudreaux and Hay 1969

Remarks:

This modern family includes Coccolithophorids bearing holococcoliths (coccoliths consisting of uniform small calcite elements).

Genus: Lucianorhabdus Deflandre 1959

Type species: Lucianorhabdus cayeuxi Deflandre 1959

Lucianorhabdus cf. L. cayeuxii Deflandre

1959 Lucianorhabdus cayeuxi Deflandre, partim, p.142, pl.4, figs.11-19, 21-24, non pl.4, figs.20,25.

1969 Lucianorhabdus cayeuxi Deflandre, Bukry, p.66, pl.40, fig.4.

1982 Lucianorhabdus cayeuxii Deflandre, Crux, pl.5.10, fig.30.

1983 Lucianorhabdus cayeuxii Deflandre, Varol, p.452, fig.5, no.24.

Figured material:

Plate 6, fig.13. UCL-2142-20. Length: 5 µm (SEM)

Occurrence:

This species is found in the Wadi Tarfa(Q. trifidum Zone-A. cymbiformis Zone), Gebel Tarbouli(Q. trifidum Zone), Wadi Mellaha(A. cymbiformis Zone-N. frequens Zone), and Gebel Atshan (L. quadratus Zone-N. frequens Zone).

Genus: Phanulithus Wind and Wise
[Syn. (Calculites Prins and Sissingh 1977)]

Type species: Tetralithus obscurus Deflandre 1959

Phanulithus obscurus (Deflandre) Wind and Wise

1959 Tetralithus obscurus Deflandre, p.138, pl.3, figs.26-29.

1964 Tetralithus obscurus Deflandre, Bramlette and Martini, p.320, pl.4, figs.26-28.

1977 Phanulithus obscurus (Deflandre) Wind and Wise, p.304, pl.31, fig.5, pl.33, figs.2-6, pl.34, figs.2,4, pl.36, fig.6.

1978 Phanulithus obscurus (Deflandre) Wind and Wise, p.141, figs.2A, 2D.

1982 Phanulithus obscurus (Deflandre) Wind and Wise, Crux, pl.5.7, fig.5, pl.5.10, figs.14-15.

Occurrence:

This species is recorded in the _Q. trifidum_ Zone at Wadi Tarfa, _N. frequens_ Zone at Gebel Tarbouli section, and throughout the Maastrichtian (_A. cymbiformis_ Zone to _N. frequens_ Zone) at Wadi Mellaha.

Genus: _Zygrhablithus_ Deflandre 1959

Type species: _Zygolithus bijugatus_ Deflandre 1954

Zygrhablithus bijugatus (Deflandre) Deflandre

1954 _Zygolithus bijugatus_ Deflandre, in Deflandre and Fert, p.148, pl.11, figs.20,21, text-fig.59.

1959 _Zygrhablithus bijugatus_ (Deflandre) Deflandre, p.135.

1979 _Zygrhablithus bijugatus_ (Deflandre) Deflandre, Romein, p.195.

Figured material:

Plate 6, fig.14. UCL-1903-11. Height: 8.8 μm (SEM)
Length of base: 5 μm (SEM)

Occurrence:

This species is found in the Upper Palaeocene (NP9) and the Lower Eocene (NP10) of Wadi Mellaha, the Upper Palaeocene (NP9) of Gebel Duwi and Gebel Um El Ghanayem and in the Lower Eocene (NP10) of Gebel Tarbouli.

Family: RHOMBOASTERACEAE new family

Type genus: *Rhomboaster* Bramlette and Sullivan 1961

Diagnosis:

This family includes genera which consist of a single calcite unit have the form of a rhombohedron with depressed faces and tri- and hexaradiate forms.

Remarks:

The genus *Marthasterites* Deflandre (1959) includes the three-rayed calcareous nannofossils constructed of one calcite crystal. This genus is restricted to the Late Cretaceous and is classified under INSERTAE SEDIS. This family is created here to include the genera *Rhomboaster* and *Tribrachiatas*. These two genera are restricted stratigraphically to the Upper Paleocene-Lower Eocene and show an evolutionary relationship. Romein (1979) mentioned that there is an evolutionary link between the genus *Rhomboaster* and genus *Micula* and has considered *Rhomboaster intermedia* Romein (1979) to have evolved from *M. decussata* (=*M. staurophora*) in the base of NP9 Zone, while the former species is transitonal between the latter species which is composed of 8 elements, and *R. bitrifida* which is composed of one calcite element. The genus *Micula* is not included in this family because *Micula* is restricted to the Cretaceous. Also, during this study *M. staurophora* was found to be very rare in the Danian sediments, and absent in younger sediments, and is considered reworked. The evolutionary relationship between *Micula* and *Rhomboaster* suggested by Romein (1979) was not observed here. The photographed specimens of *R. intermedia* by Romein (1979, pl. 10, figs. 7-9) do not demonstrate the evolution relation between the two above mentioned genera.

Genus: *Rhomboaster* Bramlette and Sullivan 1961

Type species: *Rhomboaster cuspis* Bramlette and Sullivan 1961

Remarks:

The species belong to this genus have the form of a rhombohedron with depressed faces, spine-like corners and formed of a single calcite unit. In the light microscope, cross-polarised light, the species behave as one unit and show a low order interferance colours. This group is important stratigraphically as they are abundant in many places in the world and restricted in time (from the late of *Discoaster multiradiatus* Zone to the early of *tribrachiatus contortus* Zone).

Occurrence:

Two important (stratigraphically) members of the genus *Rhomboaster* are found in Egypt. *Rhomboaster bitrifida* and *R. calcitrapa* apparently have a very narrow stratigraphic range and wide geographic extinction. They are found in most of the studied sections ranging from the top of the *D. multiradiatus* Zone (upper part of Upper Palaeocene) to the lower part of the *T. nunii* Zone (base of Lower Eocene).

Rhomboaster bitrifida Romein

1979 *Rhomboaster bitrifida* Romein, p.191, pl.7, figs.3-4, pl.10, figs.10-13.

Figured material:

Plate 7, fig.2. UCL-1892-9. Diameter: 8·3 μm (SEM).

Remarks:

The species has the form of a rhombohedron with depressed faces and corners extended like arms. Four arms (three longer ones and a very short one) are visible in the upper face. The configuration in the lower face is the mirror image of that in the upper face. Some forms have just three arms in each face without a short one.

Rhomboaster calcitrapa Gartner

1971 Rhomboaster calcitrapa Gartner, partim, p.114, pl.4, figs.4-5,6a-b, non pl.4, figs.2-3.

1971 Marthasterites spineus Shafik and Stradner, partim, p.93, text-figs.7a-c, non text-fig.7d,6.

1979 Rhomboaster calcitrapa Gartner, Romein, p.191, pl.7, fig.5.

Remarks:

This rhomboaster has the same construction as Rhomboaster bitrifida but differs in its longer arms (which, in some forms, taper outwards forming a pointed tips) and reduced rhombic body.

Gartner's specimens (1971, pl. 4, fig. 2,3) show forms with very reduced central rhombic body and very long arms which is considered to be a transitional form between Rhomboaster calcitrapa and Tribrachiatus spineus (Shafik and Stradner) Romein, particularly specimen plate 4, figure 3.

Genus Tribrachiatus Shamrai (1963) emended Romein 1979

Type species: Tribrachiatus orthostylus (Bramlette and Riedel) Shamrai 1963 (=Discoaster tribrachiatus Bramlette and Reidel 1954)

Remarks:

This genus includes species formed of a single calcite unit with three regularly spaced arms. It was emended by Romein (1979) to include forms with six regularly spaced arms (as T. spineus, T. nunnii) and six irregularly spaced arms (as T. contortus). He also mentioned that the above mentioned forms were assigned to the genus Marthasterites by many authors which is restricted to the Cretaceous. This is followed here as is not clear the link between the Mesozoic forms and the Tertiary ones although Romein (1979) considered Micula decussata is a Cretaceous-Tertiary form and the origin of Rhomboaster group while the Cretaceous forms which are present in the Early Tertiary are considered by many authors to be reworked and by others as in place and becoming extinct through the Early Palaeocene.

Tribrachiatus bramlettei (Brönnimann and Stradner) Proto Decima et al.

1960 Marthasterites bramlettei Brönnimann and Stradner, p.366, figs.17-20, 23, 24.

1971 Marthasterites nunnii (Brönnimann and Stradner) Gartner, p.116.

1975 Tribrachiatus bramlettei (Brönnimann and Stradner) Proto Decima et al., p.49, pl.4, figs.17-18.

1978 Marthasterites bramlettei Brönnimann and Stradner, Perch-Nielsen et al., pl.9, figs.53, 52; pl.22, figs.2,5.

1978 Marthasterites bramletti Brönnimann and Stradner, Abdelmalik et al., p.229, pl.5, figs.1,2.

1979 Tribrachiatus nunnii (Brönniman and Stradner) Romein, p.194.

Figured material:

Plate 7, fig.3. UCL-1892-23. Diameter: 13.3 μm (SEM)

Remarks:

This species has six regularly spaced arms. Intermediate forms between this species and R. bitrifida are obsered in the D. multiradiatus Zone and the Tribrachiatus contortus Zone.

Gartner (1971) Gave Marthastrites bramlettei Brönnimann and Stradner a new specific name M. nunnii as the former one is a junior homonym (Loeblich and Tappan 1966, p.148).

Occurrence:

This species apparently has a short stratigraphic range and wide geographic extinction. Tribrachiatus nunnii's first appearance marks the lower limit of the T. contortus Zone NP10 (Early Eocene) and it extinct within the same zone. Tribrachiatus nunnii's first appearance marks the Lower Eocene in all the studied sections except Gebel Um El Ghanayem (this section does not reach the Lower Eocene).

Tribrachiatus contortus (Stradner) Bukry

1958 Discoaster contortus Stradner, p.187, text-figs.35-36.

1961 Marthasterites contortus (Stradner) Deflandre, Stradner and Papp, p.112, pl.36, figs.1-8, text-figs. 11/8, 20/3.

1972 Tribrachiatus contortus (Stradner) Bukry, p.1081.

Figured material:

Plate 7, fig.4. UCL-1903-25.Diameter: 15 µm (SEM)

Occurrence:

The extinction level of this species marks the upper limit of the T. contortus Zone NP10 (Early Eocene). Tribrachiatus contortus is rare in the top two samples in the Lower Eocene (T. contortus Zone) at Gebel Tarbouli.

Genera: INCERTAE SEDIS

Genus Marthasterites Deflandre 1959

Type species: Discoaster? furcatus Deflandre 1954

Remarks:

Romein (1979) has considered the genus Marthasterites to be restricted to the Cretaceous. Also he emended the genus Tribrachiatus shamrai and used it instead of the former genus for the Early Tertiary forms.

Marthastrites inconspicuus Deflandre

1959 Marthastrites inconspicuus Deflandre, p.140, pl.3, figs.6-14.

1964 Marthastrites inconspicuus Deflandre, Bramlette and Martini, p.314, pl.6, fig.6.

1968 Marthastrites inconspicuus Deflandre, Gartner, p.42, pl.2, fig.9, pl.10, fig.10.

1977 Marthastrites inconspicuus Deflandre, Verbeek, p.118, pl.11, fig.10.

Occurrence:

This species is recorded in the Maastrichtian of Gebel Tarbouli, Gebel Atshan, Gebel Duwi and Wadi Mellaha sections.

Genus: Ceratolithoides Bramlette and Martini 1964

Type species: Ceratolithoides kamptneri Bramlette and Martini 1964

Ceratolithoides aculeus (Stradner) Prins and Sissingh

1961 Zygrhablithus aculeus Stradner, p.81, figs.53, 55-57.

1968 Tetralithus sp. aff. T. aculeus (Stradner) Gartner, p.43, pl.9, fig.5, pl.13, figs.5a-d.

1977 Ceratolithoides aculeus (Stradner) Prins and Sissingh, Sissingh, p.60, pl.1, fig.8.

1978 Tetralithus aculeus (Stradner) Gartner, Perch-Nielsen et al., pl.1, figs.58-59.

Figured material:

Plate 6, fig.15. UCL-1877-22. Length: 5 μm (SEM)

Ceratolithoides kamptneri Bramlette and Martini

1964 Ceratolithoides kamptneri Bramlette and Martini, p.308, pl.5, figs.13-14.

1977 *Ceratolithoides kamptneri* Bramlette and Martini, Verbeek, p.115, pl.1, fig.11.

Occurrence:

This species was recorded from the Upper Maastrichtian by many authors (Bramelette and Martini 1964, Verbeek 1977). During this work *C. kamptneri* is found in the Upper Maastrichtian strata at Gebel Tarbouli and Wadi Mellaha sections.

Genus: *Ellipsolithus* Sullivan 1964

Type species: *Coccolithites macellus* Bramlette and Sullivan 1961

Ellipsolithus macellus (Bramlette and Sullivan) Sullivan

1961 *Coccolithites macellus* Bramlette and Sullivan, p.152, pl.7, figs.11-13.

1964 *Ellipsolithus macellus* (Bramlette and Sullivan) Sullivan, p.184, pl.5, figs. 3a-b.

1977 *Ellipsolithus macellus* (Bramlette and Sullivan) Sulllivan, Perch-Nielsen, pl.42, figs.1-6; pl.43, fig.9, pl. 49, figs.12-14.

1978 *Ellipsolithus macellus* (Bramlette and Sullivan) Sulllivan, Perch-Nielsen et al., pl.10, figs.71-76; pl.22, fig.10-13.

1979 *Ellipsolithus macellus* (Bramlette and Sullivan) Sulllivan, Okada and Thierstein, pl.3, figs.9,10; pl.13, figs.7-10.

1981 *Ellipsolithus macellus* (Bramlette and Sullivan), Haq and Aubry, pl.1, figs.30,31.

Figured material:

Plate 11, fig.14. UCL-2073-27. Length: 13.3 µm (SEM)

Occurrence:

This is a good index species in the Palaeocene the first appearance of this species is recorded from Gebel Atshan (NP4a-NP10), Wadi Mellaha (NP4a-NP10), Wadi Tarfa (NP4b-NP10), Gebel Um El Ghanayem (NP4a-NP9), Gebel Duwi (NP4a-NP7/8) and Gebel Tarbouli (NP10).

Ellipsolithus distichus (Bramlette and Sullivan) Sullivan

1961 Coccolithites distichus Bramlette and Sullivan, p.152, pl.7, figs.8a-c.

1964 Ellipsolithus distichus (Bramlette and Sullivan) Sullivan, pl.184, pl.5, figs,4-6

1978 Ellipsolithus distichus (Bramlette and Sullivan) Sullivan, Perch-Nielsen et al., pl.10, figs.69, 70,73,74; pl.22, figs.7-9.

1979 Ellipsolithus distichus (Bramlette and Sullivan) Sullivan, Okada and Thierstein, pl.4, figs.la-b; pl.13, figs.11,12.

Figured material:

Plate 11, fig.15. UCL-2085-35. Length: 6.5 µm (SEM)

Occurrence:

This species is reported by many authors from the *E. macellus* Zone NP4 (Early Palaeocene) to the *T. contortus* zone (Early Eocene). This species is found in the Early Tertiary (NP5/6-NP9) in Egypt. The earliest occurrence of *E. distichus* is recorded at Gebel Atshan, Gebel Duwi, Gebel Um El Ghanayem section in the *F. tympaniformis* Zone (NP5/6).

Genus: *Scapholithus* Deflandre 1954

Type species: *Scapholithus fossilis* Deflandre 1954

Scapholithus apertus Hay and Mohler

1967 *Scapholithus apertus* Hay and Mohler, p.1534, pl.201, figs.11,12,14.

1978 *Scapholithus rhombiformis* Hay and Mohler, Perch-Nielsen et al., pl.23, fig.11.

non 1979 *Scapholithus apertus* Hay and Mohler, Romein, p.188, pl.6, fig.6.

Figured material:

Plate 7, fig.1, UCL-1964-35 (SEM)

Remarks:

This species is distinctive by its very small size (relative to other Early Tertiary nannofossils), rhomboidal outline, the presence of a central rod and smaller rods extended from the rim to the central rod.

Scapholithus apertus differs from *Scapholithus rhombiformis* Hay and Mohler 1967 by the presence of a central broad rod (which is absent in the later species) and the lower number of small rods (for *S. apertus* from 10-12) which extends from the rim into the central area.

Perch-Nielsen *et al.* (1978, pl. 23, fig. 11) showed a specimen with a clear central rod which is a basic feature to separate *S. apertus* from *S. rhombiformis*.

In Romein (1979, p. 188) considered *S. rhombiformis* Hay and Mohler and *S. apertus* Hay and Mohler to be one species and the photographs of *S. rhombiformis* by Hay and Mohler (1967) represents the proximal side of the other species. His SEM photograph (1979, pl. 6, fig. 6) showed a *Scapholithus* with small rods extending from the rim, more in number (about 16 rods) than in *S. apertus*, and no central broad rod.

Family: BRAARUDOSPHAERACEAE Delflandre 1947.

Genus: Braarudosphaera Deflandre 1947

Type Species: Pontosphaera bigelowi Deflandre 1947

Braarudosphaera bigelowi (Gran and Braard) Deflandre

1935 Pontosphaera bigelowi Gran and Braarud, p. 338, fig. 67.

1947 Braarudosphaera bigelowi (Gran and Braarud) Deflandre, p. 439, text figs. 1-5.

1981 Braarudosphaera bigelowij (Gran and Braarud) Deflandre, Smith, p.31, pl.1, figs. 48-50.

Occurrence:

Braarudosphaera bigelowi is a well-known species. It has a worldwide geographic range throughout the Cretaceous to the Recent. This species is a nearshore/shallow water indicator It is found in the Maastrichtian of Gebel Tarbouli, Wadi Tarfa, Wadi Mellaha, Gebel Duwi. Also it is recorded in the Maastrichtian and the Palaeocene of Gebel Atshan and from the Danian of Um El Ghanayem in this study. It is found rare possibly due to the effect of dissolution which is a common preservational factor effecting most of the samples.

Braarudosphaera discula Bramlette and Riedel

1954 Braarudosphaera discula Bramlette and Riedel, p. 394, pl. 38, fig. 7.

1961 Braarudosphaera discula Bramlette and Riedel, Bramlette and Sullivan, p. 153, pl.8, figs. 6a→b, 7.

1967 Braarudosphaera discula Bramlette and Riedel, Hay and Mohler, p. 1535, pl. 202, figs. 13-15.

Occurrence:

This species is recorded from the Lower Palaeocene (C. danicus Zone NP3) at Gebel Duwi section.

Family: COCCOLITHACEAE Poche 1913

Genus: Cruciplacolithus Hay and Mohler 1967

Type species: Heliorthus tenuis Stradner 1961.

Remarks:

This genus differs from the genus Chiasmolithus by:

1. the unsplit straight, and parallel or almost parallel to the axes of the ellipse crossbars. Some Chiasmolithus species have split, curved crossbars.

2. in some species, the central crossbars end with feet oriented to a particular direction (clockwise or anticlockwise), while all the Chiasmolithus species do not have feet at the end of the crossbars except Chiasmolithus consuetus which has feet but not oriented to a certain direction.

3. the wall does not have any structures while some species belonging to Chiasmolithus has a wall with a little projection into the central area.

Romein (1979, p. 100), mentioned that the position of the wall is a better diagnostic feature than the position of the central cross in the differentiation between the two genera (the wall lies in a more distal position in Chiasmolithus). This observation was not detected in the Lower Tertiary of Egypt as a basic difference between the two genera. Also the state of preservation makes it very hard to detect. Ericsonia has the same construction as in Genus Cruciplacolithus and Chiasmolithus but the former has an open central area with no central bars.

Cruciplacolithus primus Perch-Nielsen

1977 Cruciplacolithus primus Perch-Nielsen, p. 746, pl. 17, figs. 7, 8; pl. 50 , figs. 11, 12.

1979 Cruciplacolithus primus Perch-Nielsen, Okada and Thierstein, p. 522, pl. 1, figs. 5,6; pl. 9, figs. 12-14; pl.10, figs. 1,2.

1979 Cruciplacolithus tenuis (Stradner) Hay and Mohler, Okada and Thierstein, partim. pl. 10, figs. 3,4; non pl. 10, figs. 5,6, pl.1, figs.7-9.

Figured material

Plate 7, fig. 5. UCL-2085-23. Length: 8 μm (SEM).

Plate 13, fig.1. UCL-2278-18. (LM)

Remarks:

This species has a central crossbar which is parallel to the major axes of the ellipse and lacks feet. The number of elements of the distal cycle of the distal shield is equal to the number of elements of the wall and varies from 38 to 44.

This species differs from C. tenuis by the relatively larger central area, narrower margin, the absence of feet at the end of the crossbars of the central area and the wall is more steep inward.

Cruciplacolithus primus is a rare species in the studied sections. This species is considered to be highly susceptible to dissolution (Thierstein 1980). It could be the state of preservation is responsible for the absence of this species as the Danian assemblages in Egypt are poorly preserved.

Occurrence:

This species is originally described from Sao Paulo Plateau, D.S.D.P. Site 356 southwestern Atlantic Ocean from the C. tenuis Zone (NP2) Early Palaeocene by Perch-Nielsen (1977, p. 746). Cruciplacolithus primus is found within the C. danicus Zone (NP3), E. macellus Zone (NP4a) and the Fasciculithus ragaii Zone (NP4b) in Egypt. Rare specimens are found in the Fasciculithus tympaniformis Zone (NP 5/6) in Gebel Duwi section.

Cruciplacolithus tenuis (Stradner) Hay and Mohler

1961 Heliorthus tenuis Stradner, p.84, text-figs. 64, 65.

1967 Cruciplacolithus tenuis (Stradner) Hay and Mohler, p. 1527, pl. 196, figs. 29-31; pl. 198, figs 1, 17.

1977 Cruciplacolithus tenuis (Stradner) Hay and Mohler, Perch-Nielsen, pl.17, figs. 3, 5; pl. 50, figs. 3, 4.

1977 Cruciplacolithus notus Perch-Nielsen, p. 746, partim, pl. 17, fig. 4; not pl. 50, fig. 2.

1983 Cruciplacolithus tenuis (Stradner) Hay and Mohler, Varol, p.454, fig.5 (17-20).

Figured material:

Plate 7, fig. 6. UCL-2053-35. Length: 10 µm (SEM).

Plate 13, fig. 2. UCL-2278-17.

Remarks:

This species of Cruciplacolithus is characterized by broad central crossbars aligned with the major axes of the ellipse, the central area is relatively small compared to the broad margin. There are small feet at the ends of the crossbars. The number of elements of the distal cycle of the distal shield is 50 to 72.

Occurrence:

In Egypt, the last occurrence of this species is found within D. multiradiatus Zone (NP9). It is recorded from NP4a to NP9 in Wadi Mellaha and Gebel Um El Ghanayem sections, and from NP3 to NP9 in Gebel Atshan, Gebel Duwi and Wadi Tarfa sections.

Cruciplacolithus edwardsii Romein

1979 Cruciplacolithus edwardsii Romein, p.101, pl. 2, figs. 7, 8; pl. 9, figs. 9, 10.

Figured material:

Plate 7, fig. 8. UCL-2053-27. Length: 8 Um (SEM).

Remarks:

In this species, the number of elements of the distal cycle of the distal shield is 44 to 60.

Cruciplacolithus edwardsii differs from the C. tenuis in having no feet at the ends of the central crossbars and the crossbars are slightly deviated from the long and short axis of the ellipse in a clockwise direction in distal view.

Cruciplacolithus edwardsii differs from Chiasmolithus danicus in having straight thinner crossbars, the angle which the crossbars make with the main axes of the ellipse is smaller and the margin (the wall and the distal shield) is narrower. Chiasmolithus Consuetus differs from C. edwardsii in having crossbars which make a larger angle with the axes of the ellipse and end with feet.

Occurrence:

Cruciplacolithus edwardsii is originally described from Jorquera Formation, Member B (Lower Palaeocene) at Barranco del Gredero, South East Spain by Romein (1979). He has also recorded this species from the Lower Palaeocene in Israel and Scandinavia (Romein 1979, p. 25, 35, 45). This species is found in the Lower Palaeocene strata of Gebel Atshan and Gebel Duwi.

Cruciplacolithus frequens (Perch-Nielsen) Romein

1977 Chiasmolithus frequens Perch-Nielsen, p. 746, pl. 18, figs. 2,4; pl. 19, figs. 1,3,5; pl. 50, fig. 5,6.

1977 Cruciplacolithus notus Perch-Nielsen, p. 746, partim., pl.50, fig. 2; non pl. 17, fig. 4.

1979 Cruciplacolithus frequens (Perch-Nielsen) Romein, p.103, pl.9, fig.6.

Figured Material:

Plate 7, fig.7. UCL-2037-15. Length: + 11.7 µm (SEM).

Plate 13, fig. 3. UCL-2279-9. (LM)

Remarks:

Cruciplacolithus frequens shows central crossbars with feet directed anticlockwise in distal viewe. The central crossbars are slightly deviate from the main axes of the ellipse in anticlockwise direction (in distal view). This species differs from Cruciplacolithus tenuis by the small angle which the bars make with the major axes of the ellipse (The crossbars of C. tenuis are perfectly parallel to the major axes of the ellipse) also the feet at the ends of the crossbar are well developed (easy to observe in LM and SEM) and well oriented. Chiasmolithus consuetus has crossbars which make a larger angle with the long and the short axis of the ellipse compared to the angle which the crossbars of C. frequens make with the major axes of the ellipse, also the feet at the ends of the former species protrude (or point) towards the two sides of each bar but in the latter species the feet are oriented (pointed) in anticlockwise direction. The angle which the crossbars make with the major axes of the ellipse is larger in the Late Palaeocene, also variation in the shape of the outline ranged between elliptical to subcircular.

Occurrence:

Perch-Nielsen (1977, p. 746) has recorded Chiasmolithus frequens (= Cruciplacolithus frequens) throughout NP5 Zone (equal to the lowr part of NP5/6, this work) to NP9 Zones (Thanetian) from the D.S.D.P. Sites 354, 357, 358 which are located in the South of the Atlantic Ocean close to the South America Continent. Romein (1979, p. 58, 103) has restricted the vertical range of this species to NP7/8 Zone and NP9 Zone. He has recorded C. frequens from the Caravaca section S.E. Spain in NP7/8 Zone and the base of NP9 Zone and in the Nahal Avdet section, Israel in NP9 Zone. Throughout this work the first occurrence of C. frequens was recorded in the F. tympaniformis Zone (NP5/6) . It is recorded from Wadi Mellaha (NP5/6, NP9), Gebel Atshan (NP9), Gebel Um El Ghanayem (NP5/6-NP9), Gebel Duwi (NP5/6-NP9) and Wadi Tarfa (NP7/8).

Genus Campylosphaera Kamptner 1963

Campylosphaera dela (Bramlette and Sullivan) Hay and Mohler.

1961 Coccolithites delus Bramlette and Sullivan, p. 151, pl.7, figs. 1-2.

1967 Campylosphaera dela (Bramlette and Sullivan) Hay and Mohler, p. 1531, pl. 198, fig. 14.

1971 Campylosphaera eodela Bukry and Percival, p. 125, pl.1, figs. 1-4.

1976 Campylosphaera dela (Bramlette and Sullivan) Hay and Mohler. Haq and Lohmann, pl. 9, fig.3.

1978 Campylosphaera dela (Bramlette and Sullivan) Hay and Mohler, Perch-Nielsen et al., pl.12,fig.5.

1978 Campylosphaera eodela Bukry and Percival, Perch-Nielsen et al., pl.8,figs.61-62,pl.12,fig.2.

1979 Cruciplacolithus eodelus (Bukry and Percival) Romein, p. 103.

1979 Cruciplacolithus delus (Bramlette and Sullivan) Perch-Nielsen, Romein, p. 104.

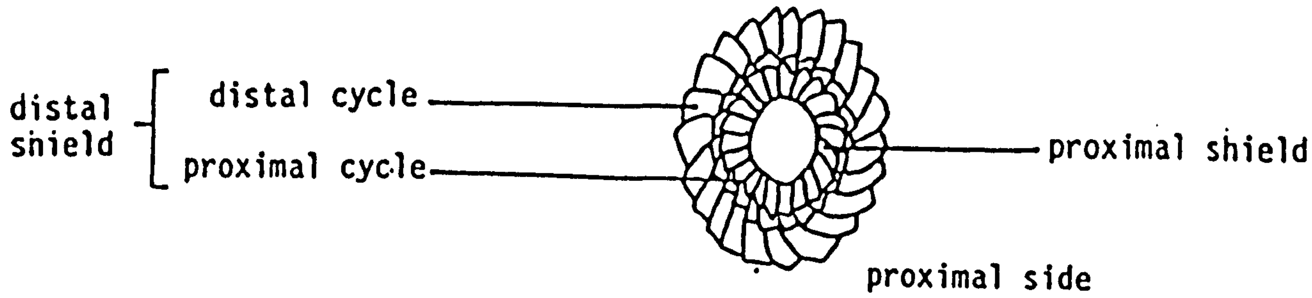
Figured Material:

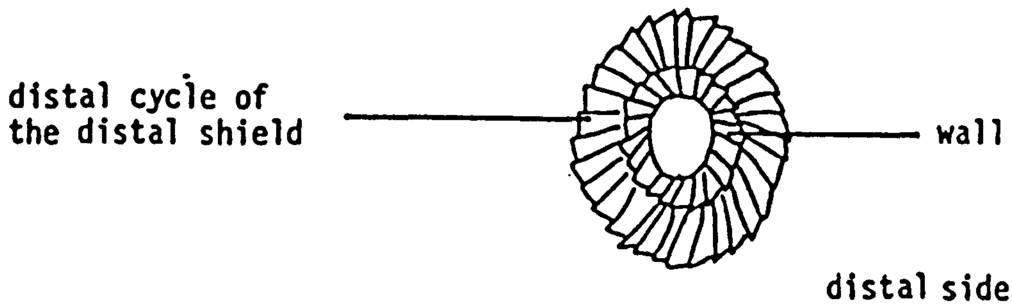
Plate 7, fig.9. UCL-1903-12. Length: 5.5 µm (SEM).

Remarks:

Small placolith, elongated elliptical to subquadrangular form. The variation in the shape of this species is due to preservational factors. From side view, the majority of the specimens are strongly curved. Some specimens have slightly deviated crossbars from the main axes of the placolith. In distal view, the elements of the distal shield imbricate clockwise and the sutures between the elements are more or less parallel to each other (except at the two far ends of the ellipse). The crossbars are always thin. In proximal view, every bar is formed of two rows of rhombic elements which form two long sutures dividing every bar into two parts. The ratio between the diameter of the central area and the width of the margin is highly variable.

Diameter (length): from 5.5 µm to 8 µm, the diameter of most of the specimens is 6 µm to 7 µm.





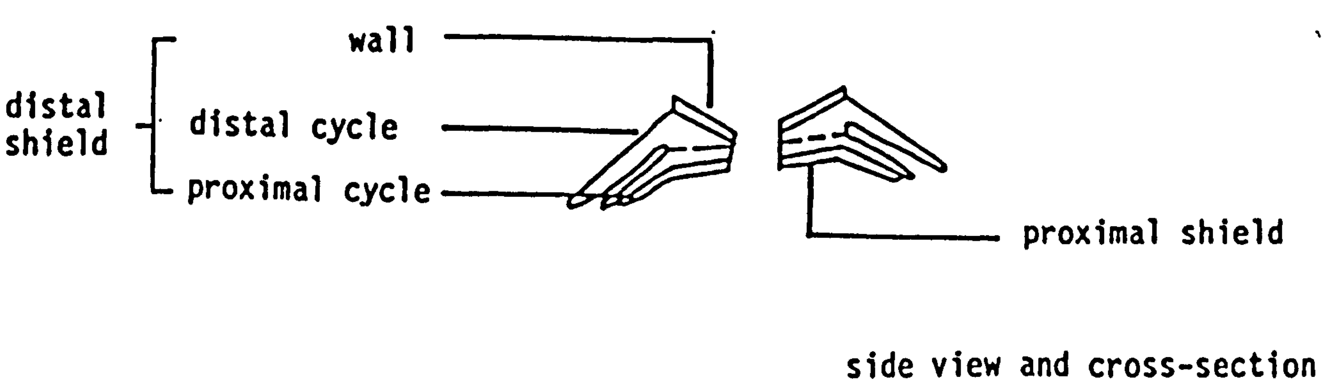


Fig.52–Schematic drawings of the significant features of the genus Ericsonia Black 1964

The differentiation between Campylosphaera dela and Campylosphaera eodela mentioned by Bukry (1971) and Romein (1979) is considered interaspecific variation or due to dissolutin and overgrowth. This is because both forms first occur in the Late Palaeocene of Egypt at the same stratigraphic level.

Genus: Ericsonia Black 1964

Type species: Ericsonia occidentalis Black 1964

Discussion:

The genus Ericsonia is considered a junior synonym of Coccolithus by some authors while others regard it as distinct and use the name. SCHWARZ (1894), p.346) proposed the genus Coccolithus and stated "for all the forms hitherto described, recent and fossil, the one name Coccolithus oceanicus, mihi". He illustrated two specimens for this species (p.343, figs.8-9), without citing the source of his material and failed to designate a type specimen. Thus Braarud et.al. (1964, p. 397) designated the specimen figures as Coccosphaera pelagica by Wallich (1877, pl.17, fig.1) as lectotype for C. oceanicus Schwarz 1894. Black (1964, p.311) introduced the genus Ericsonia for "circular or elliptical coccoliths with a will defined central opening surrounded by three or more apparently concentric rings of granules which are differently oriented in adjacent rings". He described three species as members of the genus (including the type species E. occidentalis) from sediments of Palaeogene age from seamounts in the Atlantic Ocean. Romein (1979, p.104) studied the holotype of the type species of Ericsonia and compared it with the type species of Coccolithus i.e. Coccosphaera pelagica Wallich 1877 (lectotype designated by Braarud et. al. 1964) and concluded that the genus Ericsonia differs from the genus Coccolithus by the presence of a well differentiated proximal cycle of the distal shield (which projects beyond the proximal shield) in proximal view and can be used for a group of Palaeocene and Eocene coccoliths which have the above mentioned marginal construction. In this work I prefered to use this genus, rather than the genus Coccolithus, because the type species (Coccosphaera pelagica Wallich 1877) of Coccolithus does not show any detailed marginal construction compared with the holotype of the type species of Ericonia (E. occidentalis). Some illustrated specimens of Coccolithus pelagicus from Neogene sediments do not show the significant differentiated proximal cycle of the distal shield in proximal view. For example, the specimen illustrated by Perch-Nielsen from Pliocene sediments (1972, pl.2, fig.2) and by Steinmetz and Stradner (1984, pl.3, fig.7: as Coccolithus carteri which is actually a variety of C. pelagicus from the Pleistocene). In my material or any illustrated material I came across for this species (from Palaeogene sediments) only forms with well differentiated proximal cycle of the distal shield were observed.

Ericsonia cava (Hay and Mohler) Perch-Nielsen

1967 Coccolithus cavus Hay and Mohler, p. 1524, pl. 196, figs. 1-3; pl. 197, figs. 5,7,10,12.

1969b Ericsonia cava (Hay and Mohler) Perch-Nielsen, p. 61, pl. 2, figs. 7-8.

1973 Coccolithus cavus Hay and Mohler, Roth, p. 729, pl. 14, figs. 1-2,4-5.

1979 Ericsonia subpertusa Hay and Mohler, Okada and Thierstein, partim., pl. 11, fig.4, non pl.2, figs.8-10; pl. 11, figs.5-9.

Figured Material:

Plate 7, fig. 10. UCL-1951-8. Length: 5 µm (SEM)

Plate 13, fig.4: UCL-2278-15. (LM)

Remarks:

This species is elliptical to subelliptical in plan view and composed of a relatively high margin (compared to the margin of the Ericsonia eopelagica). The wall and the distal shield are composed of 36 to 50 elements.

Ericsonia cava can be distinguished from E. subpertusa by:

1. its elliptical shape while the latter is circular.

2. in side view the distal shield is relatively less steep than the distal shield of E. subpertusa.

3. in distal view, the sutures on the wall of E. cava are straight or slightly curved in an anticlockwise direction but the sutures on E. subpertusa are hook-shaped.

4. in E. cava the wall is steeper inward compared to the wall of E. subpertusa.

Ericsonia cava differs from E. eopelagica by:

1. in distal view (or side view) the distal shield is steeper outward.

2. the distal cycle of the distal shield is narrower in E. cava than in E. eopelagica.

Ericsonia subpertusa Hay and Mohler

1964 Markalius inversus (Deflandre) Bramlette and Martini, partim., p. 302, pl.7, figs. 2a-b, non pl. 2, figs. 4-9.

1967 Ericsonia subpertusa Hay and Mohler, p. 1531, pl. 198, figs. 11,15,18; pl. 199, figs. 1-3.

1976 Ericsonia subpertusa Hay and Mohler, Haq and Lohmann, pl. 1, figs. 7-8.

1977 Ericsonia subpertusa Hay and Mohler, Perch-Nielsen, pl. 16, figs. 3,11, pl. 50, fig. 22.

1979 Ericsonia subpertusa Hay and Mohler, Okada and Thierstein, partim., pl. 2, figs. 8-10; pl. 11, figs. 5-9, non pl. 11, fig. 4.

Figured Material:

Plate 7, fig. 11. UCL-2053-6. Diameter: 6 µm (SEM)
Plate 13, fig. 5. UCL-2278-21. (LM).

Description:

This species is circular to subcircular in plan view. The number of elements of the distal cycle of the distal shield is 34 to 50. It is difficult to observe the hook-shape sutures of the wall (in distal view) due to poor preservation with secondary calcite overgrowth obscuring the sutures. The elements of the wall and the elements of the distal cycle of the distal shield imbricate clockwise. On the proximal side, the elements of the inner cycle (the proximal shield) imbricate clockwise, the elements of the proximal cycle of the distal shield imbricate anticlockwise and the elements of the distal cycle imbricate clockwise.

Remarks:

In progressively later assemblages (Late Palaeocene), this species is larger, with a large central area and the distal shield is steeper.

Ericsonia subpertusa differs from E. eopelagica in:

1. its more circular shape.

2. the steeper distal shield (in side view).

3. the suture of the wall of the former species is hook-shaped while it is straight in the wall of the latter species.

Occurrence:

This is a well known species throughout the Palaeocene and Early Eocene on a worldwide scale. It is recorded here, in all the studied areas as throughout the Lower Tertiary sediments.

Ericsonia eopelagica (Bramlette and Riedel) Romein

1954 Tremalithus eopelagicus Bramlette and Riedel, p.392, pl.38, figs.2a-b.

1961 Coccolithus crassus Bramlette and Sullivan, p. 139, pl.1, figs. 4a-d.

1964 Ericsonia ovalis Black, p.312, pl.52, figs.5-6.

1979 Coccolithus eopelagicus (Bramlette and Riedel) Bramlette and Sullivan, Okada and Thierstein, pl. 1, figs. 3a-b.

1979 Coccolithus pelagicus (Wallich) Schiller, Okada and Thierstein, pl. 1, figs. 4a-b; pl. 9, figs.9-11.

1979 Ericsonia eopelagica (Bremlette and Riedel) Romein, p.108.

Figured Material:

Plate 7, fig. 12. UCL.-2085-6. Length: 8 μm (SEM)

Plate 13, fig. 6. UCL-2278-29.

Remarks:

Bramlette and Riedel (1954) introduced this speciees name for large sized (16-20μm), elliptical coccoliths which have a high number of elements in their margin and an elongate central slot (opening). Romein (1979) used this name to include similarly constructed early Tertiary coccoliths with smaller size and fewer elements. The proximal side of "eopelagica" shows the characteristic construction of the cycles as in the holotype of the type species of the genus Ericsonia Black (1964), p.113).

Occurrence:

Ericsonia eopelagica is a well known species. This species has been recorded from Palaeogene sediments by others. It is consistently present and usually abundant from the E. macellus Zone NP4a (Lower Palaeocene) to the T. contortus Zone NP10 (Lower Eocene) in the Early Tertiary samples investigated during this work.

Ericsonia robusta (Bramlette and Sullivan) Perch-Nielsen

1961 Cyclolithus ? robustus Bramlette and Sullivan, p. 141, pl. 2, fig. 7a-c.

1977 Ericsonia cf. E. robusta (Bramlette and Sullivan) Perch-Nielsen, pl. 16, figs. 1,4-6, pl.50, figs. 34-35.

1977 Ericsonia robusta (Bramlette and Sullivan) Perch-Nielsen, pl.16, figs. 2,7, pl.50, fig.23.

Figured Material:

Plate 7, fig. 13. UCL-2080-1. Diameter: +4 μm (SEM)

Occurrence:

Bramlette and Sullivan (1961, Table 1) recorded Cyclolithus ? robustus (= E. robusta) from the base of the Lodo Formation of California where it appears in Heliolithus riedelii Zone (= top of D. mohleri Zone NP 7/8 of Late Palaeocene age). This species is found rare in the Upper Palaeocene (D. multiradiatus Zone) in Gebel Atshan, and Gebel Um El Ghanayem sections. The earliest occurrence of E. robusta is in the F. tympaniformis Zone (NP5/6) at Wadi Mellaha and Wadi Tarfa sections.

Ericsonia sp. A.

Diagnosis:

This species is distinguished by its small size and circular outline.

Description:

This is a small, circular to subcircular species with an open central area. In distal view, the distal shield is formed of a cycle of slightly imbricating elements. The number of elements in this cycle is 25 to 30. The wall hasthe same number of elements as the distal shield. The sutures between the elements of the distal shield and the wall are straight. Diameter: 4-6 μm

Figured material:

Plate 7, fig. 14, UCL-2062-37 (SEM)
Plate 7, fig. 15, UCL-2045-27 (SEM)
Plate 13, fig. 7 , UCL-2281-21 (LM)

Remarks:

This species is distinguished from E. cava by its smaller size, fewer elements in the distal shield, its more circular outline and more gently outward sloping distal shield.

Occurrence:

This species is found (rare) in the upper Palaeocene at Um El Ghanayem section, Gebel Atshan and at Gebel Duwi section.

Genus: Chiasmolithus Hay, Mohler and Wade 1966

Type Species: Tremalithus oamaruensis Deflandre 1954.

Remarks:

The species belonging to the genus Chiasmolithus are elliptical to sub-elliptical in plane view and composed of a distal shield, a wall, proximal shield and a central area spanned by diagonal crossbars.

Gartner (1970) split the species of the Chiasmolithus genus into two groups according to the construction of the cross-bars and their behaviour in LM/CP. The first group includes C. consuetus, C. californicus and C. titus have crossbars composed of tabular calcite elements one on top of the other and in LM/CP the bars behave as one homogeneous unit. The second group includes C. bidens, C. solitus, C. eograndis, C. expansus, and C. gigas which show on the proximal side of the crossbars, laths interfingering with each other along and perpendicular to the axes of the crossbars. On the distal side the crossbars show laths parallel to the axes of the crossbars. In LM/CP the crossbars of the central area of this group show an extinction line along the axis of each bar which give it a split appearance.

Genus Chiasmolithus differs from the genus Cruciplacolithus in the presence of oblique central cross bars (not aligned with the major axes of the ellipse) while the crossbars of the species belonging to the latter genus are aligned with the major axes of the ellipse. Also see (Remarks, on genus Cruciplacoliths)

Chiasmolithus danicus (Brotzen) Hay and Mohler

1959 Cribrosphaerella danica Brotzen, p. 25, text-fig.9.

1967 Chiasmolithus danicus (Brotzen) Hay and Mohler, p. 1526, partim.; pl. 196, figs 16,21-22; non pl. 198, figs 8,12-13.

1976 Chiasmolithus danicus (Brotzen) Hay and Mohler, Haq and Lohmann, pl. 3, figs, 5-7.

1979 Chiasmolithus danicus (Brotzen) Hay and Mohler, Okada and Thierstein, partim., pl. 10, figs. 9-10; non pl. 2, fig. 5.

1979 Chiasmolithus danicus (Brotzen) Hay and Mohler, Romein, p. 113, pl. 3, fig. 1.

Figured Material:

Plate 8, fig. 1. UCL-2053-18. Length: 7 μm (SEM)

Remarks:

The wall and the distal cycle of the distal shield have the same number of elements, each composed of about 60 elements.
Romein (1979, p. 113), mentioned that in LM/CP the bars of the central area of this species display a pattern which is intermediate between that of the species of the first Chiasmolithus group and the second Chiasmolithus group. This is observed through this study. The bars are broad and strong, one (which is close to the long axis) is more or less straight and the other is curved and somewhat off-set in the centre. The contact between the two crossbars is almost parellel to the long axis of the placolith. The SEM photographs of Chiasmolithus danicus (Brotzen) Hay and Mohler (1967, pl. 198, figs. 8, 12, 13) do not represent this species. Figures 12 and 13 represents a placolith with crossbars slightly deviated from the major axes of the ellipse with very clear feet at the ends of the bars. Figure 8 is highly overgrown and it is difficult to see the construction of the central area. Okada and Thierstein (1979, pl.2, fig.5) produced a light microscope photograph of C. danicus which is more related to Cruciplacolithus tenuis.

Occurrence:

Chiasmolithus danicus is the zonal marker of the C. danicus Zone NP3 (Early Palaeocene). The highest occurrence of this species is recorded in the lower part of the Fasciculithus ragaae Zone in Wadi Tarfa section.

<u>Chiasmolithus</u> <u>consuetus</u> (Bramlette and Sullivan) Hay and Mohler

1961 <u>Coccolithus</u> <u>consuetus</u> Bramlette and Sullivan, p. 139, pl. 1, figs. 2a-c.

1967 <u>Chiasmolithus</u> <u>consuetus</u> (Bramlette and Sullivan) Hay and Mohler, partim., p. 1526, pl. 198, fig. 16, non pl. 196, figs.23-25.

1967 <u>Chiasmolithus</u> <u>danicus</u> (Bramlette and Sullivan) Hay and Mohler, partim., p. 1526, pl. 198, figs. 12-13, non pl. 196, figs. 16,21-22, pl. 198, fig.8.

1967 <u>Chiasmolithus</u> <u>bidens</u> (Bramlette and Sullivan) Hay and Mohler, partim., p. 1526, pl. 196, figs. 14-15,17, non pl. 197, figs. 4,9,14.

1977 <u>Chiasmolithus</u> <u>consuetus</u> (Bramlette and Sullivan) Hay and Mohler, Perch-Nielsen, pl. 19, figs. 2,4,6; pl. 50, figs, 7-8.

1978 <u>Chiasmolithus</u> <u>consuetus</u> (Bramlette and Sullivan) Hay and Mohler, Perch-Nielsen et al., pl. 8, figs. 79-80; pl. 11, fig. 11.

non 1979 <u>Chiasmolithus</u> <u>consuetus</u> (Bramlette and Sullivan) Hay and Mohler, Okada and Thierstein, pl. 2, figs. 3-4; pl. 11, figs. 1-2.

1979 <u>Chiasmolithus</u> <u>consuetus</u> (Bramlette and Sullivan) Hay and Mohler, Romein, p. 113.

Figured Material:

Plate 8, fig. 2. UCL-2063-13. Length: 8.5 µm (SEM).
Plate 13, fig. 15. UCL-2279-29. (LM).

Remarks:

The presence of triangular elongated feet at the ends of the crossbars is very characteristic for C. consuetus. However, these feet are slightly obscure or completely absent in etched specimens. The crossbars are perpendicular to each other. Some specimens have one off-set bar and others have both crossbars slightly offset. Early specimens are small and subelliptical or subrounded, but in the D. mohleri Zone and the D. multiradatus Zone they are larger and more elliptical. The number of elements of the distal cycle of the distal shield is 42 to 50.

Hay and Mohler's LM photographs (1967, pl. 196, figs. 23-25) represent Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler. These LM photographs show dark extinction lines splitting the central crossbars (in LM/CP), and tooth-like projections in the central area. Hay and Mohler's LM-photograph (1967, pl. 196, figs. 14, 15, 17) of Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler is Chiasmolithus consuetus because of the presence of feet at the ends of the crossbars, the bars are straight and in cross-polarized light (pl. 196, fig. 17), no central extinction line in the middle of the central bars is seen. Perch-Nielsen, Sadek, Barakat and Teleb (1978) illustrated Chiasmolithus nitidus Perch-Nielsen. This species has the same construction of Chiasmolithus consuetus. Also, they illustrated another specimen to represent Chiasmolithus consuetus (see synonymy list), the absence of the feet at the ends of the bar is due to the effect of dissolution. Okada and Thierstein's Chiasmolithus consuetus specimens (see synonymy list) represent Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler.

Length: 7-12 µm

Occurrence:

This species has a worldwide geographic distribution throughout the Early Tertiary. This form is rare to common in the Early Tertiary of the studied areas in Egypt. The first occurrence of C. consuetus is in the E. macellus Zone NP4a (at Gebel Duwi, Gebel Atshan and Gebel Um El Ghanayem).

Chiasmolithus californicus (Sullivan) Hay and Mohler

1964 Coccolithus californicus Sullivan, p.180, pl.2, figs.3-4.

1967 Chiasmolithus californicus (Sullivan) Hay and Mohler, p.1527, pl.196, figs.18-20; pl.198, fig.5.

1970 Chiasmolithus californicus (Sullivan) Hay and Mohler, Gartner, p.941, fig.8.

1976 Chiasmolithus californicus (Sullivan) Hay and Mohler, Haq and Lohmann, pl.9, fig.7; pl.3, fig.9.

1979 Chiasmolithus californicus (Sullivan) Hay and Mohler, Okada and Thierstin, pl.2, figs.2a-b, pl.10, fig.11-12.

Figured Material:

Plate 8, fig.3. UCL-1882-10. Length: 16.6 µm (SEM)

Remarks:

This species shows the same construction as Chiasmolithus consuetus. Chiasmolithus californicus differs from Chiasmolithus consuetus by:

1. The former is larger than the latter
2. The crossbars of C. californicus have no feet at their ends

The separation of these two similar species is significant stratigraphically as the first appearance of C. consuetus is detected in the Early Palaeocene while C. californicus occurs at the end of the Palaeocene and the Early Eocene.

Length: 14-17 µm.

Occurrence:

Hay and Mohler (1967, p. 1511) have recorded C. californicus in the D. multiradiatus Zone NP9 (Late Palaeocene) at Pont Labau, Southern France. Romein (1979, p. 25, 35) has recorded this species from the T. contortus Zone NP10 (Early Eocene) to the D. sublodoensis (Middle Eocene) at Caravaca section S.E. Spain and from the D. multiradiatus (NP9) to T. orthostylus Zone (Early Eocene) at Nahal Avdat section, Israel. During this work, C. californicus is rarely found in the D. multiradiatus Zone (NP9) at Gebal Atshan, and Wadi Tarfa Sections. At Gebal Duwi Section it is rarely found from the top of the D. multiradiatus Zone (NP9) to the T. contortus Zone (NP10) (Lower Eocene) and at Gebel Tarbouli C. californicus is found in the T. contortus Zone NP10 (Lower Eocene).

Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler

1961 Coccolithus bidens Bramlette and Sullivan, p.139, pl.1, fig.1.

1964 Coccolithus bidens Bramlette and Sullivan, Sullivan, p.180, pl.1, figs.10a-b.

1967 Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler, partim, p.1526; pl.197, figs.4,9,14, non pl.196, figs. 14-15,17.

1967 Chiasmolithus consuetus (Bramlette and Sullivan) Hay and Mohler, partim, p.1526, pl.196, figs. 23-25, non pl.198, fig.16.

1976 Chiasmolithus eograndis Perch-Nielsen, Haq and Lohmann, pl.1X, fig.11.

1976 Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler, Haq and Lohmann, pl.1x, fig.8.

1978 Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler, Perch-Nielsen et al., pl.8, figs.77-78, pl.11, figs.1,4.

1979 Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler, Okada and Thierstein, pl.2, fig.1a-b, pl.10, figs.7-8.

1979 Chiasmolithus consuetus (Bramlette and Sullivan) Hay and Mohler, Okada and Thierstein, pl.2, figs.3-4, pl.11, figs.1-2.

Figured material:

Plate 8, fig. 4. UCL 1972-33 Length: 10.5 μm (SEM)

Remarks:

This species has one bar of the central area is straight and the other is offset into two parts (fig.33). Both of the parts are parallel or subparallel to the short axis of the placolith. Chiasmolithus bidens is the oldest species (has which cross bars with a perfect split appearance in cross-polarised light) of the second Chiasmolithus group (group with split bars in cross-polarised light). The SEM of the distal side of the cross bars of the central area shows it to consist of elongated prismatic elements which are parallel to the axes of the bars. The number of these elements are about four on each bar. In younger assemblages (Late Palaeocene) specimens have two wall developed tooth-like projections extending from the wall into the central area. In the older assemblages (Danian) from Egypt very rare specimens has a little indentation but the majority of the specimens have no protrosions. This may be due to the poor preservation which the predominate state of the Early Palaeocene assemblages.

Haq and Lohmann's SEM photograph of Chiasmolithus eograndis (1976, Pl. IX, fig. 11) is most probably Chiasmolithus bidens as the central area has a crossbar with one straight bar and the other strongly offset. The characteristic tooth-like projections are absent due to overgrowth and dissolution which obscure the delicate details of the specimen. Okada and Thierstein's specimens representing Chiasmolithus consuetus (Bramlette and Sullivan) Hay and Moher (1979, pl. 2, figs. 3, 4 and pl. 11, figs. 1, 2) are actually Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler. The light microscope photographs (plate 2, figs. 3, 4) do show small lateral identations and crossbars with one bar straight and the other offset, also the central cross has the split appearance in phase contrast (pl. 2, fig. 3b) and in phase contrast of the other specimen (pl. 2, fig. 4b). Their SEM photograph (pl. 11, fig. 1, 2) shows one straight bar and the other split into two parts.

Occurrence:

This form is found common in the Lower Tertiary samples of the studied sections from Egypt. Chiasmolithus bidens's earliest occurrence is recorded in the E.macellus Zone(NP4a)from Gebel Duwi, Gebel Athsan and Wadi Mellaha sections .

Chiasmolithus eograndis Perch-Nielsen

1971d Chiasmolithus eograndis Perch-Nielsen, p.16, pl.10, figs.5-6; pl.13, figs.1-4; pl.60, figs.17-18.

1975 Chiasmolithus eograndis Perch-Nielsen, Edwards and Perch-Nielsen, pl.6, figs.6, 10, 14-15; pl.7, figs.4,7.

non 1976 Chiasmolithus eograndis Perch-Nielsen, Haq and Lohmann, pl.IX, fig.11 .

1978 Chiasmolithus eograndis Perch-Nielsen, Perch-Nielsen et al., pl.8, figs.69-70.

Figured material:

Plate 8, fig.5, UCL-2084-16 Length: 10.5 μm (SEM)

Occurrence:

In this study C. eograndis is found in the T. contortus Zone NP10 (Lower Eocene) at Gebel Duwi, Gebel Atshan, Gebel Tarbouli and Wadi Mellaha sections.

Family: PRINSIACEAE Hay and Mohler 1967

Genus: Prinsius Hay and Mohler 1967

Type Species: Coccolithus bisulcus Stradner 1963

Remarks: This genus differs from genus Ericsonia black (1964) by:

1. a species belonging to the former genus have a closed or almost closed central area, while the species belonging to the latter genus have an opened central area.

2. generally Prinsius species are smaller in size than Ericsonia species.

3. the central area of Prinsius species is constructed of two superimposed cycles of elements (Lower centro-distal cycle and upper centro-distal cycle). The central area of Ericsonia species is constructed of an opening surrounding by one cycle of elements (The wall).

Genus Prinsius differs from genus Toweius Hay and Mohler (1967) by:

1. in the former genus the central area is closed or almost closed, while in the latter the central area is not.

2. in the genus Prinsius the upper centro-distal cycle is composed of elements with irregular arrangement. In genus Toweius the elements of the upper centro-distal cycle are more regularly constructed.

3. the species of genus Prinsius are older and smaller in size (except Prinsius bisulcus) than the species of the genus Toweius.

Prinsius dimorphosus (Perch-Nielsen) Perch-Nielsen

1969a Biscutum? dimorphosus Perch-Nielsen, p.318, pl.32, figs.1-4; text-fig.1.

1969b Biscutum? dimorphosus Perch-Nielsen, Perch-Nielsen, p.57, pl.4, figs.6-12.

1972 Biscutum? dimorphosus Perch-Nielsen, Perch-Nielsen, pl.8, fig.2.

1977 Prinsius dimorphosus (Perch-Nielsen) Perch-Nielsen, p.794, pl.30, figs.10-13.

Figured material:

Plate 8, fig.6. UCL-1951-12. Diameter: 3 μm (SEM)

Remarks:

Very rare species, all the specimens examined are circular and all of them show 11 elements in each cycle. The diameter of this species is 2.5 μm to 3 μm.

Prinsius martinii (Perch-Nielsen) Haq

1969a Ericsonia? martinii Perch-Nielsen, p.324, pl.32, figs.3b, 5-7, text-fig.2.

1971 Prinsius martinii (Perch-Nielsen) Haq, partim, p.18, pl.5, figs.2-3,5,10, non pl.5, fig.1.

1976 Prinsius martinii (Perch-Nielsen) Haq, Haq and Lohmann, pl.1, fig.5; pl.14, figs.1-2.

1977 Prinsius martinii (Perch-Nielsen) Haq, Perch-Nielsen, pl.30, fig.3.

1978 Prinsius martinii (Perch-Nielsen) Haq, Perch-Nielsen et al., pl.18, figs.4, 10.

Figured material:

Plate 8, fig.7. UCL-2042-10. Length: 4 μm (SEM)

Remarks:

This species is characterised by its elliptical shape, the central area is closed by the irregularly arranged elements of the upper centro-distal cycle and the elements of the two far ends of the distal cycle of the distal shield is broader than the other elements of the same cycle. This species differs from *Prinsius bisulcus* (Stradner) Hay and Mohler by:

1. the central area of *P. martinii* is closed by the elements of the upper centro-distal cycle, while in *P. bisulcus* the central area is almost closed and has small pores (about 4 to 8 pores).

2. *Prinsius bisulcus* in light microscope (phase contrast) has a more distinctive dark line at either end of the long axis of the central area.

3. generally *P. martinii* is smaller with less elements (25-35 elements, Length: 3.5-5.5 μm) in the distal cycle of the distal shield than *P. bisulcus* (30 to 40 elements, length: 5-9 μm).

Also, *Prinsius martinii* differs from the elliptical form of *Prinsius dimorphosus* (Perch-Nielsen) Perch-Nielsen in:

1. the number of elements of the distal cycle of the distal shield of *Prinsius martinii* (25 to 35) is higher than the number of elements of the distal cycle of the distal shield of *Prinsius dimorphosus* (11 elements).

2. the diameter (length) of the former species (3.5-5.5 μm) is also more than the diameter of the latter one (2.5-3 μm).

Prinsius bisulcus (Stradner) Hay and Mohler

1963 Coccolithus bisulcus Stradner, in Gohrbandt, p.72, pl.8, figs.3-6, text-fig.3(1a-b).

1967 Prinsius bisulcus (Stradner) Hay and Mohler, p.1529, pl.196, figs.10-13, pl.197, fig.6.

non 1971a Prinsius bisulcus (Stradner) Hay and Mohler, Perch-Nielsen, fig.15.

1973 Prinsius bisulcus (Stradner) Hay and Mohler, Roth, p.732, pl.17, fig.2.

1977 Prinsius bisulcus (Stradner) Hay and Mohler, Wise and Wind, pl.6, figs.3-6.

1979 Prinsius bisulcus (Stradner) Hay and Mohler, Okada and Theirstein, pl.3, figs.4-5; pl.12, figs.12-14.

Figured material:

Plate 8, fig.8. UCL-1995-5. Length: +3.5 μm(SEM)

Remarks:

This species has an elliptical elongated shape. The central area is almost closed or slightly opened and has a very small pores (about 4 to 8 pores). The elements ofthe two far ends ofthe distal and the proximal shields are broader than the rest of elements of each cycle of the shields. In the light microscope (phase contrast) a distinctive dark line along the long-axis, at each side of the central area is present. This dark line besides the presence of perforations in the central area and the large diameter (length), distinguishes this species from P. martinii and the elliptical form of Prinsius dimorphosus.

Perch-Nielsen's drawing (1971a, fig.15) of the distal side of Prinsius bisulcus does not represent the perforations of the central area and also it shows the central area of the above mentioned species is smaller than the central area of Prinsius martinii (Perch-Nielsen 1971a, fig.15) which is not recognised in this study as a basis for distinguishing the two species.

Genus: Toweius Hay and Mohler 1967

Type species: Toweius craticulus Hay and Mohler 1967.

Remarks:

The species of the genus Toweius are subelliptical, elliptical, subcircular or circular in shape. The species are constructed of a distal shield (which is composed of a distal cycle and a narrower proximal cycle) a proximal shield (which is composed of one cycle of elements) and two superimposed cycles of elements in the central area.

Genus Toweius differs from the genus Prinsius Hay and Mohler by:

1. the species of the former genus have a thicker and more regularly constructed upper centro-distal cycle than the upper centro-distal cycle of the latter genus.

2. the central area of the species of genus Toweius perforate or open while the central area of the species of the genus Prinsius is closed or has very narrow perforations (e.g. P. bisulcus).

The genus Toweius differs from the genus Ericsonia Black (1964) by

1. most species of the genus Toweius have a perforated central area and few have a completely open central area. All species of the genus Ericsonia have an open central area.

2. the central area of the species of Toweius are constructed of open or perforated area surrounded by two partly superimposed cycles of elements. The central area of the species of the genus Ericsonia is constructed of an open central area surrounded by one cycle of elements (the well).

In the SEM, the species of the genera Prinsius and Toweius have on their distal side, two partly superimposed cycles of elements in the central area with a distinctive serrate outer margin.

Toweius pertusus (Sullivan) Romein

1965 Coccolithus pertusus Sullivan, p.32, pl.3, figs. 5-6.

1967 Toweius craticulus Hay and Mohler, p.1530, pl.196, figs.7-9, pl.197, figs.2-3.

1967 Toweius helianthus (Hay and Towe) Hay and Mohler, p.1530, pl.197, fig.8.

1975 Toweius craticulus Hay and Mohler, Edwards and Perch-Nielsen, pl.3, figs.3,6,8-9; pl.8, fig.2.

1977 Toweius craticulus Hay and Mohler, Perch-Nielsen, pl.30, fig.4.

1978 Toweius craticulus Hay and Mohler, Perch-Nielsen et al., pl.18, figs.1,9,12-13,16-17,20 .

1978 Toweius rotundus Perch-Nielsen, in Perch-Nielsen et al., p.352, pl.18, figs.34,35, pl.18, figs.4,15,18-19.

1979 Toweius craticulus Hay and Mohler, Okada and Thierstein, pl.3, figs.6a-b, pl.13, figs.1,2.

1979 Toweius pertusus (Sullivan) Romein, p.124, pl.3, fig.9.

Figured material:

Plate 8, fig.9. UCL-1964-22.Length: 4 μm (SEM)

Remarks:

This species is elliptical to subcircular in shape. The central area is peforated and the number of pores varies from 6 to 26. Variation in the shape of Toweius pertusus and the poor preservation (overgrowth and dissolution of the central area) made previous authors split this form into other species (see the synonymy list).

Toweius eminens (Bramlette and Sullivan) Gartner

1961 Cocolithus eminens Bramlette and Sullivan, p.139, pl.1, figs.3a-d.

1967 Cruciplacolithus eminens (Bramlette and Sullivan) Hay and Mohler, partim, p.1527, pl.196, figs.26-28, non pl.198, figs.9-10.

1971 Toweius eminens (Bramlette and Sullivan) Gartner, p.114, pl.5, figs.4-6.

1978 Toweius eminens (Bramlette and Sullivan) Gartner, Perch-Nielsen et al., pl.3, figs.55-56; pl.18, figs.6-7.

1979 Toweius eminens (Bramlette and Sullivan) Gartner, Okada and Thierstein; pl.3, figs.7a-b; pl.13, figs.3-4.

Non 1979 Toweius eminens (Bramlette and Sullivan) Gartner, Romein, p.125, pl.4, fig.1.

Figured material:

Plate 8, fig.10 UCL-1964-12.Length: 5 μm (SEM)

Remarks:

This species is subcircular in shape with 4 large openings in the central area. The number of elements of the distal cycle of the distal shield is 34 to 46 elements. In well preserved assemblages, this species displays a grill under the opening of the central area of the distal side.

Toweius tovae Perch-Nielsen

1971c Toweius tovae Perch-Nielsen, p.359, pl.13, figs.1-3, 5; pl.14, figs.8-9.

1978 Toweius tovae Perch-Nielsen, Perch-Nielsen et al., pl. 18, fig.11.

Figured material:

Plate 8, fig.11. UCL-1964-2.Length:+5.5 μm (SEM)

Remarks:

The outline of this species is subellipitical with 6 or 7 openings in the central area. The number of elements of the distal cycle of the distal shield is about 42. Toweius tovae differs from Toweius eminens in:

1. the outline of T. eminens in plan view is subcircular, while the outline of T. tovae is subelliptical.

2. in side view the distal shield of T. eminens is more steep or higher than the distal shield of the T. tovae.

3. the number of perforations in the central area of _Toweius tovae_ is more than the number of perforations in the central area of the _T. eminens_.

4. the perforations of _T. eminens_ are larger than the perforations of _T. tovae_.

Also _Toweius tovae_ differs from _T. pertusus_ in:

1. the former species is subelliptical, while the latter species is elliptical to subcircular in shape.

2. _Toweius tovae_ has fewer and larger perforations in the central area.

Family: SPHENOLITHACEAE Deflandre 1952

Genus: _Sphenolithus_ Deflandre 1952

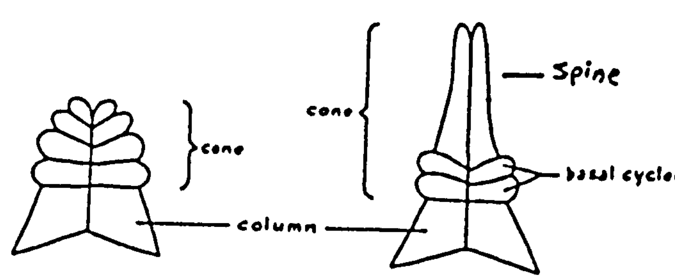


Fig.53 - Schematic drawings to illustate some descriptive terms of the genus _Sphenolithus_ Deflandre 1952 (after Romein 1979, p.144).

Type species: _Sphenolithus radians_ Deflandre 1952

Sphenolithus primus Perch-Nielsen

1971c _Sphenolithus primus_ Perch-Nielsen, p.357, pl.11, fig.4, pl.12, figs.4-5,7-12; pl.14, figs.22-24.

1972 Sphenolithus primus Perch-Nielsen, Perch-Nielsen, pl.16, fig.10.

1978 Sphenolithus primus Perch-Nielsen, Perch-Nielsen et al., pl.8, figs.46-47; pl.20, figs.2-4.

Figured material:

Plate 8, fig.12 UCL-2081-1. Diameter: 8 μm (SEM)
Height: 7.5 μm

Remarks:

This species has the form of a dome in side view. Sphenolithus primus is constructed of a column composed of 8 to 10 elements and a cone consisting of three to four superimposed cycles of elements. The diameter of the column is 4-8 μm. The height is 4-9 μm, but most of the specimen's heights are between 4 and 5 μm.

Sphenolithus moriformis (Brönnimann and Stradner)
Bramlette and Wilcoxon 1967

1960 Sphenolithus moriformis Brönnimann and Stradner, p.368, figs.11-16.

1967 Sphenolithus moriformis (Brönnimann and Stradner) Bramlette and Wilcoxon, p.124, pl.3, figs.1-6.

1971a Sphenolithus moriformis (Brönnimann and Stradner) Bramlette and Wilcoxon, Perch-Nielsen, fig.17.

1977 Sphenolithus moriformis (Brönnimann and Stradner) Bramlette and Wilcoxon, Perch-Nielsen, pl.32, fig.11.

1982 Sphenolithus moriformis (Brönnimann and Stradner) Bramlette and Wilcoxon, Hamilton and Hojjatzadah, pl.6.4, figs.1,2, pl.6.5, figs. 26-27.

Figured material:

Plate 8, fig.13, UCL-2063-27·Diameter: 4 µm (SEM)
Height : 6 µm

Remarks:

Sphenolithus moriformis is distinguished from Sphenolithus primus by the cylindrical shape of its column, where the latter species has a conical column.

Sphenolithus anarrhopus Bukry and Bramlette

1969 Sphenolithus anarrhopus Bukry and Bramlette, p.140, pl.3, figs.5-8.

1978 Sphenolithus anarrhopus Bukry and Bramlette, Perch-Nielsen et al., pl.8, figs.48-50.

1979 Sphenolithus anarrhopus Bukry and Bramlette, Okada and Thierstein, pl.5, figs.9a-c, pl.16, figs.5-8.

Remarks:

This species is distinguished by the presence of a long broad element radially extending from the centre of the cone.

Sphenolithus editus Perch-Nielsen

1978 Sphenoliths editus Perch-Nielsen, in Perch-Nielsen et al., p.352, pl.8, figs.4, 5, 11-13, 16-18, 22-27, 43-45; pl.20, figs.5-19.

Figured material:

Plate 8, fig.14, UCL-1903-7 Diameter: 3 Um (SEM)
Height :+3 Um

Occurrence:

Originally described from the Lower Eocene (NP11 Zone) strata of Gebel Gurnah section opposite Luxor, Egypt by Perch-Nielsen (1978, p. 352). She has recorded S. editus throughout the D. binodosus Zone NP11 (Early Eocene) only. During this work S. editus is found in the T. contorus Zone NP10 (Early Eocene) at Gebel Tarbouli and Wadi Mellaha sections.

Family: FASCICULITHACEAE Hay and Mohler 1967

Genus: Fasciculithus Bramlette and Sullivan 1961

Type species: Fasciculithus involutus Bramlette and Sullivan 1961

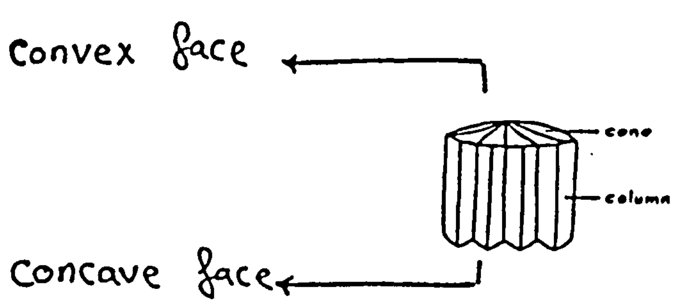


Fig.54 - Schematic drawings to illustrate some descriptive terms of the genus Fasciculithus Bramlette and Sullivan 1961 (after Romein 1979, p.147).

Remarks:

This group has the form of a short cylinder with one side convex, conical, pointed or elongated known as the convex face and the other side which is considered the concave face. The species belonging to this genus are composed of a more or less cylindrical column superimposed on a pointed or convex cone. The column is constructed of radially arranged wedge-shaped elements. In some species these elements form a concave side "Facies" which are decorated by small holes. The cone is formed of the same number of elements or less than those of the column.

Genus Fasciculithus differs from the Genus Bomolithus Roth by:

1. generally species of the former genus are constructed of two cycles of elements while the species of the latter genus are constructed of 3 cycles of elements.

2. the column of some Fasciculithus species is decorated by small holes, while none of the species of Bomolithus show these holes.

Fasciculithus ulii Perch-Nielsen

1971c Fasciculithus ulii Perch-Nielsen, p.350, pl.2, figs.1-4, pl.14, figs.17-18.

1973 Fasciculithus cf. F. ulii Perch-Nielsen, Roth, partim, p.734, pl.16, figs.2a-b, non pl.16, figs.1a-d.

1977 Fasciculithus ulii Perch-Nielsen, Perch-Nielsen, pertim, pl.10, figs.18-20, pl.49, figs.23-25, non pl.11, figs.1-3.

1978 Fasciculithus ulii Perch-Nielsen, Perch-Nielsen et al., pl.15, fig.8.

1979 Fasciculithus ulii Perch-Nielsen, Okada and Theirstein, pl.6, figs.7-8, pl.17, fig.7.

1983 Fasciculithus ulii Perch-Nielsen, Varol, p.455, fig.5 (5-6).

Occurrence:

This species is recorded from Spain and Israel by Romein (1979) in NP4 and NP5. Fasciculithus ulii is found to be a good marker species in Egypt as it ranges from the upper part of the E. macellus Zone (NP4a) to the lower part of the F. tympaniformis Zone (NP5/6). It is recorded from Gebel Um El Ghanayem (NP5/6), Gebel Atshan (NP4a-NP5/6) and Wadi Mellaha (NP4b-NP5/6).

Fasciculithus janii Perch-Nielsen

1971c Fasciculithus janii Perch-Nielsen, p.352, pl.5, figs.1-4, pl.14, figs.37-39.

1973 Fasciculithus sp. cf. F. ulii Perch-Nielsen, Roth, partim p.734, pl.16, figs.1a-d, non pl.16, figs.2a-d.

1977 Fasciculithus janii Perch-Nielsen, Perch-Nielsen, pl.12, figs.2-5, 8-18, pl.49, fig.26.

1979 Fasciculithus pileatus Bukry, Okada and Thierstien, pl. 6, figs.2-3; pl.17, fig.2-3.

1979 Fasciculithus janii Perch-Nielsen, Romein, p.150, pl.5, fig.1.

1979 Fasciculithus bitectus Romein, p.149, pl.9, fig.15.

Figured material:

Plate 9, fig.3. UCL-2080-7. Diameter: 9.5 μm (SEM)
Height :+5 μm

Remarks:

Fasciculithus pileatus which was illustrated by Okada and Thierstein (1979) and Fasciculithus bitectus which was described and illustrated by Romein (1979) are considered here to be F. janii with an etched cone.

Fasciculithus tympaniformis Hay and Mohler

1967 Fasciculithus tympaniformis Hay and Mohler, in Hay et al., p.447, pl.8, figs.1-5, pl.9, figs.1-5.

1975 Fasciculithus tympaniformis Hay and Mohler, Edward and Perch-Nielsen, pl.1, figs.2-8, pl.5, figs.1-3.

1977 Fasciculithus tympaniformis Hay and Mohler, Perch-Nielsen, pl.10, figs.22-23.

1978 Fasciculithus tympaniformis Hay and Mohler, Perch-Nielsen et al., pl.9, figs.15-16, pl.15, figs.10-11.

1978 Fasciculithus involutus Bramlette and Sullivan, Abdel malk et al., p.227, pl.3, figs. 5, 6.

1983 Fasciculithus tympaniformis Hay and Mohler, Varol, p.455, fig.5(3-4).

Figured material:

Plate 9, fig.4. UCL-2042-20. Diameter: 4.5 μm (SEM)
Height: +5 μm
Plate 13, fig.10 UCL-2279-4 (LM)

Occurrence:

Fasciculithus tympaniformis is the zonal marker of F. tympaniformis Zone (NP5/6). The first appearance of this species marks the lower boundary of the above mentioned zone. It is recorded throughout its vertical range (NP5/6-NP10) in the studied localities from Egypt.

Fasciculithus bobii Perch-Nielsen

1971c Fasciculithus bobii Perch-Nielsen, p.351, pl.1, fig.6, pl.3, fig.1-6; pl.14, figs.34-36.

1978 Fasciculithus bobii Perch-Nielsen, Perch-Nielsen et al., pl.9, figs.21-22.

Figured material:

Plate 9, fig.5. UCL-2063-1. Diameter: 3.5 µm (SEM)
Height : +3 µm
fig.6. UCL-1964-14. Diameter: 6.5 µm (SEM)
Height : +4 µm
Plate 13, fig.11 UCL-2279-3 (LM)

Remarks:

Fasciculithus bobii differs from the F. tympaniformis by the presence of a cycle of holes at the top of the column and in LM/CP the median extension line is straight not curved near the cone as in the latter species.

Occurrence:

Romein (1979, p. 25,35) has recorded F. bobii from the Discoaster multiradiatus Zone NP9 (Late Palaeocene) of the Caravaca section (S.E.Spain) and from the NP7/8 and NP9 Zones of the Nahal Avdat Section, Israel. During this work, F. bobii is recorded (rare) from the upper part of the Fasciculithus tympaniformis Zone (NP5/6) to the lower part of the D. multiradialus Zone(NP9)at Gebel Duwi Section. At Gebel Atshan, and Wadi Mellaha, F. bobii is found rare in the D. Multiradiatus Zone.

Fasciculithus billii Perch-Nielsen

1971c *Fasciculithus billii* Perch-Nielsen, p.352, pl.4, fig.11, pl.5, figs.5-10, pl.14, figs.31-33.

Figured material:

Plate 9, fig.7. UCL-2068-19. Diameter: 6 μm (SEM
Height : +3 μm

Plate 13, fig.9. UCL-2279-5 (LM)

Remarks:

The cone of this species is very low and difficult to see in poorly preserved specimens. This species has incisions or deep furrows along the column.

Fasciculithus tonii Perch-Nielsen

1971c *Fasciculithus tonii* Perch-Nielsen, p.354, pl.7, fig.4, pl.14, figs.15-16.

Figured material:

Plate 9, fig.8. UCL-2045-6. Diameter: 13.3 μm (SEM)
Height : 13.3 μm

Remarks:

A large form with a column and two to three superimposed cycles of holes. The number of elements in the column is 18 to 30. Most specimens has 20 elements. The number of elements in the cone is about half the number of the elements in the column. The cone terminates in a point. The elements of the cone are straight, but curved slightly near the pointed top of the cone in a clockwise direction.

Occurrence:

Fasciculithus tonii was recorded by Perch-Nielsen (1971c, p. 348) in the D. multiradiatus Zone NP9 (Late Palaeocene) from the Bay of Biscay DSDP Site 119. Romein (1979, p. 25,35) has recorded this species from the NP9 at Caravaca Section Southeast Spain and in the same zone at Nahal Avdet section, Israel. In this study F. tonii is found rarely at the upper part of NP5/6, NP7/8, NP9 Zones at Gebel Duwi Section.

Fasciculithus alanii Perch-Nielsen

1971c Fasciculithus alanii Perch-Nielsen, p.355, pl.7, figs.1-3; pl.9, fig.4, pl.14, figs.13-14.

Remarks:

This species has a characteristic high elongated cone and a short column.

Fasciculithus involutus Bramlette and Sullivan

1961 Fasciculithus involutus Bramlette and Sullivan, pl.14, figs.1-5.

1967 Fasciculithus involutus Bramlette and Sullivan, Hay and Mohler, p.1537, pl.203, figs.1,3,6,9; pl.204; figs.4,8-9.

1978 Fasciculithus involutus Bramlette and Sullivan, Perch-Nielsen et al., pl.9, figs.17-18.

Figured material:

Plate 9, fig.9. UCL-2063-21. Diameter: 6 μm (SEM)
Height : 6.5 μm

Remarks:

This cylindrical species consists of a parallel-sided column and low or nearly flat (at the top) cone. The column is composed of long elements with holes which are arranged in a vertical rows on the column. Each face of the column has one large hole at the top and 2 rows of holes at the bottom. Each row consists of two or three holes. The number of elements in the column is 18 to 26 but most specimens are composed of 20 elements.

Fasciculithus involutus differs from F. tympaniformis by:

1. the former species has a cycles of holes on the column while the latter has not.

2. in plane view, F. involutus has a star shaped outline, while the outline of F. tympaniformis is rosette-like.

3. in the LM/CP, the side view of F. involutus shows a straight median extinction line, while F. tympaniformis shows a straight median extinction line along the column which curves at the top towards the convex face.

Occurrence:

Hay and Mohler (1967, p. 1511) have recorded F. involutus throughout the D. multiradiatus Zone (Late Palaeocene) at Pont Labau, Southern France. Perch-Nielsen (1971C, p. 348) has recorded this species from the base of the B. Kleinpellii Zone (equal the upper part of NP5/6 Zone, this work) to the D. multiradiatus Zone NP9 (Late Palaeocene) from the Bay of Biscay (D.S.D.P. Site 119).

Romein (1979, p. 24, 34) has recorded this species from the D. multiradiatus Zone (Late Palaeocene) from Nahal Avdat Section, Israel and Caravaca section South eastern Spain. In page 77 he put the vertical range from Top of the NP9 Zone to the base of NP10 Zone. This species is found(commonly)throughout the Upper Palaeocene D. multiradiatus Zone and the earliest samples of the Lower Eocene (NP10) strata investigated throughout this work except at Gebel Duwi where the first occurrence of F. involutus is detected at the top of the D. mohleri Zone (NP7/8).

Fasciculithus schaubii Hay and Mohler

1967 Fasciculithus schaubi Hay and Mohler, p.1536, pl.203, figs.2,4,7,10, pl.204, figs.1-3, 5-7.

1971a Fasciculithus schaubi Hay and Mohler, Perch-Nielsen, fig.11.

1971c Fasciculithus schaubi Hay and Mohler, Perch-Nielsen, p.354, pl.7, fig.6; pl.9, fig.1, pl.14, figs.25-27.

1976 Fasciculithus schaubi Hay and Mohler, Haq and Lohmann, pl.4, figs.11-12.

Figured material:

Plate 9, fig.10. UCL-2076-30.Diameter: +4 μm(SEM)
Height : +4 μm

Remarks:

This relatively large species consists of a broad parallel-sided or slightly divergant (towards the distal side) column topped by a long pointed cone. Most of the specimens show a column with 6 faces, but few specimens have 4 or 8 faces. Each face has two vertical rows of three or four holes overlain by a large hole at the top. These large holes are rectangular in shape and deeper than the others. Generally the dimensions of the holes of the column gradually decrease towards the concave face.

Fasciculithus ragaae n. sp.

Derivation of name: After Ragaa M. Abdel Baky, my mother.

Diagnosis:

This species has a characteristic hat-like shape formed by the cone and the median cycle (Fig.55).

Description:

This species is composed of a high column and a low cone. The column is constructed of long wedge-shaped elements. At the top of the column there is a cycle (median cycle) of elongate elements which imbricate clockwise. On the convex face these elements extend into the cone. The cone is formed of a cycle of long, slightly oblique and imbricating elements. Each cycle of this species is composed of 20 to 38 elements.

Figured Material:

Plate 9, figures 1, 2. UCL-1995-2, 6 (SEM)
Plate 13, figure 12. UCL-2278-22 (LM)

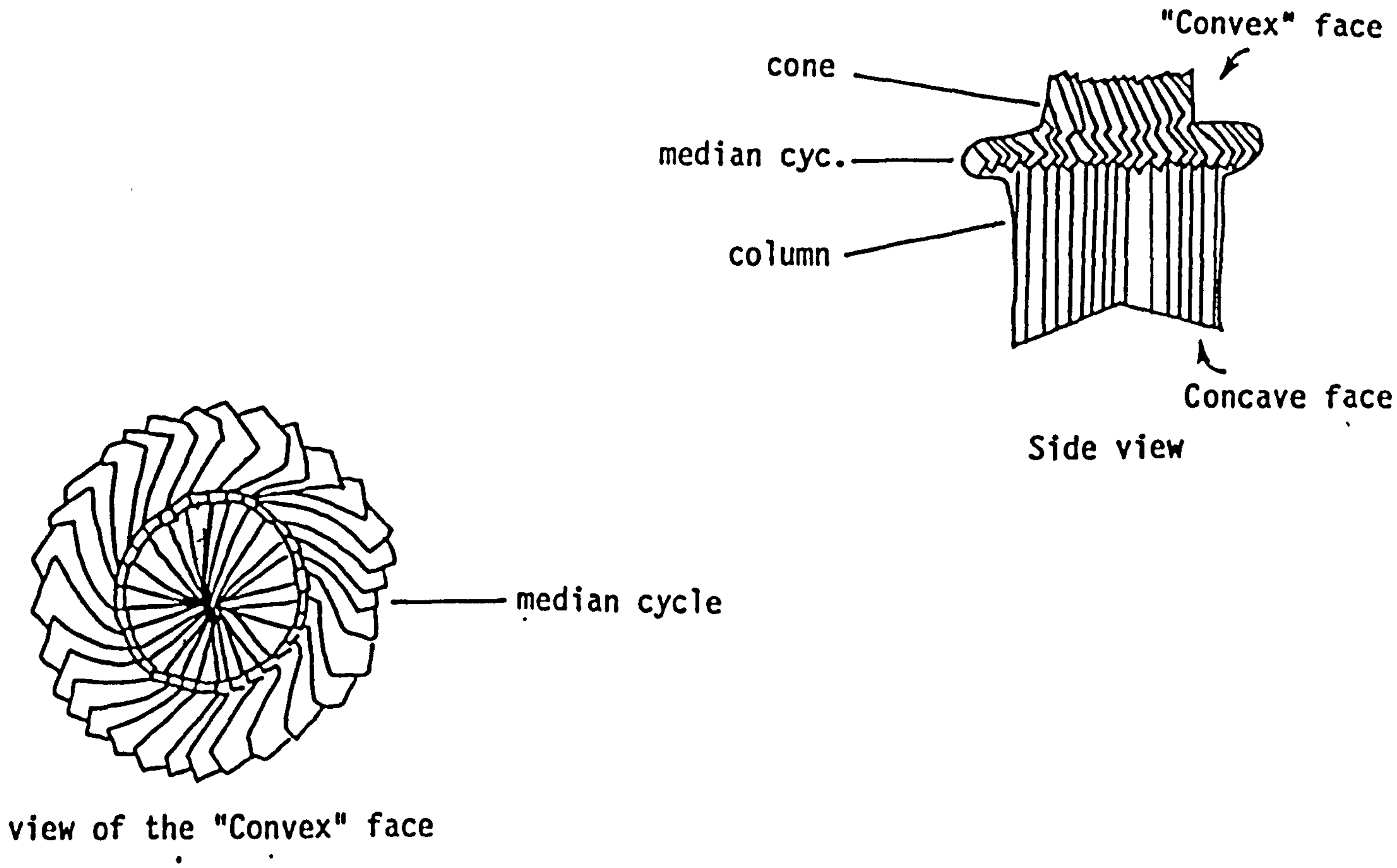


Fig.55-Schematic drawings of the significant features of Fasciculithus ragaae n.sp.

Dimensions:

Diameter of the column: 5-7 μm; Height: 5.8 μm.

Remarks:

This species differes from F. ulii by its higher cone and the diameter of the median cycle is larger than the diameter of the column while in F. ulii the diameter of the median cycle is smaller than that of the column.

Occurrence:

The first appearance of this species marks the lower limit of the Fasciculithus ragaae Zone (NP4b).

This zone is found in all the studied sections except Gebel Tarbouli section. The last occurrence of the F. ragaae is limited to the upper part of the Fasciculithus tympaniformis Zone (NP5/6).

Holotype: Pl. 9, Fig. 2, Gebel Atshan samples (18), NP5/6 Zone.

Paratype: Pl. 9, Fig. 1, Gebel Atshan sample (18), NP5/6 Zone.

Type locality: Gebel Atshan, F. tympaniformis Zone (NP5/6).

Age: Late Palaeocene (NP4b to NP5/6).

Fasciculiths gelelii n. sp.

Derivation of name: After M.A.Abdel Gelel, my father.

Diagnosis:

Large Fasciculithus with column flaring outwards from its two far ends.

Description:

This species is composed of a column flaring outwards and a cone which is conical in shape. The column consists of 15 to 25 wedge-shaped elements.

Dimensions:

Height: 10-15 μm, Diameter : 8-12 μm.

Figured Material:

Plate 8, Fig. 15, UCL-2062-2 (SEM)
Plate 9, Fig. 11, UCL-2068 (SEM)
Plate 9, Fig. 12, UCL-1964-23 (SEM)
Plate 13, Fig. 8, UCL-2279-1 (LM)

Remarks:

This species is distinguished from F. billii by its more flaring column, larger size, the more elongate conical cone and the absence of elongate holes along the column.

Holotype: Pl. 9, fig.12, Gebel Atshan Sample (22), NP9 Zone.

Paratype: Pl. 8, Fig. 15, Gebel Atshan, Sample (20), middle part of NP5/6 Zone.

Type locality: Gebel Atshan, NP9 Zone.

Age: Late Palaeocene (NP5/6-NP9).

Family: HELIOLITHACEAE Hay and Mohler 1967

Genus: *Heliolithus* Bramlette and Sullivan 1961

Type Species: *Heliolithus riedeli* Bramlette and Sullivan 1961

Heliolithus riedelii Bramlette and Sullivan

1961 *Heliolithus riedeli* Bramlette and Sullivan, p.164, pl.14, figs.9a-c, 10-11.

1971b *Heliolithus riedeli* Bramlette and Sullivan, Perch-Nielsen, p.54, pl.1, fig.4, pl.7, figs.28-29,39-40.

1971b *Heliolithus* ?sp. Perch-Nielsen, p. 68, pl.1, fig.5.

1979 *Heliolithus riedelii* Bramlette and Sullivan, Okada and Thierstein, pl.4, figs.4-6, pl.14, figs.8-9.

Figured material:

Plate 10, fig.3, UCL-2077-14 Diameter: 5 μm (SEM)
Height : +2 μm

Occurrence:

Heliolithus riedelii is the zonal marker of the *H. riedelii* Zone Bramlette and Sullivan 1961 (equal the upper part of the *D. mohleri* Zone Hay 1964 emended Romein 1979). This species has a narrow stratigraphic range (from upper part of NP7/8 to the lower part of NP9). Romein (1979, p. 54), due to the absence of *H. riedelii* in most of his sections, suggested that this species might have a limited geographical distribution. This is probable because the short vertical range of the *H. riedelii* might suggests its weak tolerance to the palaeoenvironmental changes. This species is found rare at Gebel

Atshan section at the base of D. multiradiatus Zone (Upper Palaeocene). The absence of H. riedelii in the other sections probably due to gap of sampling or the effect of poor preservation.

Genus: Bomolithus Roth 1973

Type Species: Bomolithus elegans Roth 1973

Remarks:

In this genus, coccoliths consisting of three superimposed cycles of elements are included (Fig.56). Heliolithus kleinpelii, H. cantabriae and H. megastypus are transferred to the genus Bomolithus, because the type species of genus Heliolithus, H. riedelii is constructed of two cycles of elements.

Bomolithus elegans Roth

1971b Heliolithus? sp. Perch-Nielsen, pl.2, fig.8.

1973 Bomolithus elegans Roth, p.734, pl.15, figs.1-6.

1977 Bomolithus elegans Roth, Perch-Nielsen, pl.12, fig.1.

1978 Bomolithus elegans Roth, Perch-Nielsen et al. p..9, figs.5-6,25-28, pl.16, figs.7-8,11; pl.17, figs.8-9,11.

1978 Fasciculithus cf. F. janii Perch-Nielsen, in Perch-Nielsen et.al., partim. pl.15, fig.5, non pl.15, fig.2.

1979 Heliolithus elegans (Roth) Romein, p.156, pl.5, fig.6.

Figured material:

Plate 9, fig.13. UCL-2069-2 Diameter: 8 μm (SEM)
Height : +4 μm

Plate 13, fig.13. UCL-2281-11 (LM)

Remarks:

This species is composed of a column of variable height (most of the specimens have a high column but rare ones show a low column), wide median cycle and an outer cycle slightly smaller in diameter than the median cycle. Most specimens examined do not have a clear outer cycle as this cycle is delicate and easily etched. The SEM photographs for this species by Perch-Nielsen et al. (1978, pl.16, figs.7,8,11) from Egypt show a clear outer cycle. The column consists of a long wedge-shaped element. The number of these elements is 25 to 35 (the same as the number of elements of the median cycle).

Bomolithus elegans differ from the Bomolithus cantabriae Perch-Nielsen by:

1. in side view, the outer cycle is larger than the median cycle in the B. cantabriae, while in B. elegans the median cycle is slightly larger than the outer one.

2. in side view, the largest cycle (the outer cycle) of B. cantabriae is truncated, while the largest cycle (median cycle) of B. elegans is pointed.

3. in side view, the angle which the outer cycle of B. cantabriae makes with the column is more or less 90° while in B. elegans (the median cycle) the angle is much greater than 90°.

4. the centre of B. elegans is closed, while it is open in B. cantabriae.

Bomolithus elegans is considered to be the ancestor of B. megastypus by reduction of the outer cycle and increasing in the width of the median cycle.

Perch-Nielsen's SEM photograph (1971b, Pl. 2, fig. 8) of Heliolithus? sp. is considered B. elegans with an etched outer cycle.

Perch-Nielsen's SEM photograph of F. cf. F. janii (1978, Pl. 15, fig.5) shows two cycles and a long, slightly tapering column. The outer cycle is slightly smaller than the inner one (median cycle).

Bomolithus megastypus (Bramlette and Sullivan) n. comb

1961 Discoasteroides megastypus Bramlette and Sullivan, p.163, pl.13, figs.14-15.

1971b Discoasteroides megastypus Bramlette and Sullivan, Perch-Nielsen, pl.1, fig.6.

1977 Discoasteroides megastypus Bramlette and Sullivan, Perch-Nielsen, pl.10, figs.6-16.

1978 Heliolithus cantabriae Perch-Nielsen, Perch-Nielsen et al., partim. Pl.16, figs.3,6, non pl.9, figs.9, 10, pl.15, figs.1,3,6; pl.16, figs.2,4,9,12, pl.17, figs.2-3,12.

1979 Heliolithus megastypus (Bramlette and Sullivan) Romein, p.157, pl.5, figs.7-8.

Figured material:

Plate 9, fig.14. UCL-2085-7. Diameter: 6.5 µm (SEM)
Height : +3 µm
Plate 9, fig.15, UCL-2085-1. Diameter: 6.5 µm (SEM)
Height : +2 µm

Remarks:

This species is composed of three superimposed cycles of elements, which differ in thickness and diameter. The column is high and has a shorter diameter than the median cycle which is the largest cycle. The outer cycle is smaller and less thick than the above mentioned two cycles. The column is constructed of 20 to 35 elements, but the number of elements of most specimens is 20 to 25.

Romein (1979) changed the generic name of this species to Heliolithus as the specimens of this species have a heliolithic stem as a separate structure and the type species of genus Discoasteroides, Discoasteroides kuapperi Stradner (1959), has a stem as a part from the basal disc.

This species differs from Bomolithus elegans by:

1. the median cycle (relative to the diameter of the column) of Bomolithus megastypus is larger than the median cycle (relative to the diameter of the column) of Bomolithus elegans.

2. the outer cycle is thinner, (narrower) and more delicate in Bomolithus megastypus than the outer cycle of B. elegans.

Occurrence:

Perch-Nielsen (1977, p. 715) has recorded B. megastypus from NP6 Zone (equal to the upper part of NP5/6, this work), NP8 Zone (equal to the top of D. mohleri Zone NP7/8) and the base of NP9 Zone (Late Palaeocene) at Ceara Rise in the western part of the Atlantic Ocean, near the north-eastern part of the South American continent, Site 354, DSDP. Romein (1979, p. 25,35) has reported this species from the top of NP7/8 Zone at Caravaca section, south-east Spain and from the top of NP7/8 Zone to NP9 Zone (Late Palaeocene) from Nahal Avdat Section, Israel. In this work this species is found in the studied sections. At Gebel Atshan and Gebel Um El Ghanayem sections B. megastypus was found in the base of NP9 Zone. At Wadi Tarfa section it is recorded in NP7/8 Zone. The earliest occurrence of this species is found at Gebel Duwi in NP5/6 Zone.

Bomolithus cantabriae (Perch-Nielsen) n. comb

1971b Heliolithus cantabriae Perch-Nielsen, p.55, pl.2, figs.1,3,5,7, pl.7, figs.33-36.

1976 Fasciculithus rotundus Haq and Lohmann, p.182, pl.4, figs.8-9(?)

1977 Heliolithus? cantabriae Perch-Nielsen, pl.13, figs.9, 13,17.

1978 Heliolithus? cantabriae Perch-Nielsen, Perch-Nielsen et al., partim, pl.9, figs.9-10; pl.15, figs.1, 3(?), 6(?). pl.16, figs.2, 9, 12; pl.17, fig.12, non pl.16, figs.3-4,6,9,12; pl.17, figs.2-3.

1978 Fasciculithus cf. F. janii Perch-Nielsen, Perch-Nielsen et al., partim, pl.15, fig.2, non pl.15, fig.5.

1979 Heliolithus cantabriae Perch-Nielsen, Okada and Thierstein, pl.4, figs.2a-b.

1979 Fasciculithus sp.1 Okada and Thierstein, pl.6, figs.10a-b.

Figured material:

Plate 10, fig.1 UCL-2077-7. Diameter: 8.8 µm (SEM)
Height : +6.6 µm
Plate 13, fig.14. UCL-2278-31 (LM)

Remarks:

This species is constructed of three well differentiated cycles of elements. The number of elements is the same in each cycle, 25 to 40 elements. These cycles are:

1. the column: is high and parallel-sided. The elements are large elongated and wedge-shaped. These elements thin towards the centre of the cylinder. The sutures between the elements are straight.

2. the median cycle: This cycle has the form of a thin disc and its diameter is slightly larger than the diameter of the column.

3. the outer cycle: very wide, almost flat and the elements are truncated in side view (compare with B. elegans, see remarks under B. elegans). The diameter of the outer cycle: 7-11 µm.

Heliolithus kleinpellii Sullivan evolved from the older species B. cantabriae by reduction of the column height and increase the diameter of the outer cycle.

Bomolithus cantabriae differs from H. kleinpellii by:

1. in side view, the column of B. cantabriae is higher than the column of H. Kleinpellii.

2. the central opening of the former species is narrower than the central opening of the latter species.

3. the outer cycle of H. kleinpellii is flat, while it is flat to slightly concave in B. cantabriae.

Bomolithus cantabriae differs from B. elegans by:

1. the outer cycle of the former species is larger than the median cycle, while the outer cycle of the latter species is slightly smaller (or equal) than the median cycle.

2. in side view, the median cycle (the largest cycle) of B. elegans is pointed (towards the edge), while the outer cycle (the largest cycle) of B. cantabriae is truncated.

3. Bomolithus cantabriae has a central opening, while there is no opening in the centre of B. elegans.

Heliolithus kleinpellii Sullivan

1964 Heliolithus kleinpelli Sullivan, p.193, pl.12, figs.5a-b.

1967 Heliolithus kleinpelli Sullivan, Hay and Mohler, p.1531, pl.199, figs.4-7, pl.200, figs.1,4.

1977 Heliolithus kleinpellii Sullivan, Perch-Nielsen, pl.50, fig.21.

1978 Heliolithus kleinpellii Sullivan, Perch-Nielsen et al., pl.9, figs.7,8,11-14, pl.16, figs.1,5, pl.17, 1, 4-7.

1978, Heliolithus cantabriae Sullivan, Perch-Nielsen et al., partim, pl.17, figs.2,3, non pl.9, figs. 9,10; pl.15, figs. 1, 3, 6; pl.16, figs. 2-4,6,9,12; pl.17, fig.12.

1978 Heliolithus kleinpelli Sullivan, Abdelmalik et al., p.227, pl.3, figs.2a-b.

1979 Heliolithus kleinpellii Sullivan, Okada and Thierstein, pl.4, figs. 7,8, pl.14, figs.5-7.

Figured material:

Plate 10, fig.2. UCL-2077-4 Diameter: 13.3 μm (SEM)
Height : 4.4 μm

Remarks:

This species is distinguished by its three superimposed truncated short cycles with an open central canal.

Perch-Nielsen's SEM photographs (1978, pl.17, figs.2, 3) of B. cantabriae are considered an overgrown H. kleinpelii with its distinctive short column and broad outer cycle.

Occurrence:

The stratigraphic range of this species is narrow and it has a wide geographic extinction throughout the Late Palaeocene. It is observed in NP5/6 Zone and NP7/8 Zone at Gebel Duwi and Wadi Tarfa sections. Also in NP9 Zone at Wadi Mellaha and Gebel Atshan sections.

Family: DISCOASTERACEAE Vekshina 1959

Genus: Discoaster Tan Sin Hok 1927

Type species: Discoaster pentaradiatus Tan Sin Hok 1927

Remarks:

The species is rosette-shaped or star-shaped in plan view. In side view they are biconvex, concavo-convex or plano-convex. The species show a low birefringence (except for few with a thick stem or central processes) and radial symmetry. Some discoasters bear a knob or a stem in their centre on one or both sides. Most species have straight sutures on one side (facies inferior of Stradner, in Stradner and Papp 1961) and curved sutures (in anticlockwide direction) on the other side (facies superior of Stradner, in Stradner and Papp 1961). The use of "superior" and "inferior" to describe the sides of Discoaster group is a convention used by some workers and does not necessarily indicate a relationship to the original cell.

Discoaster group shows morphologic changes throughout time since the Late Palaeocene which makes it an important group in biostratigraphic studies for the Cenozoic era. Generally the Late Palaeocene and Eocene forms have numberous rays (or arms) and robust, in contrast, Neogene discoasters are delicate and have less rays (or arms).
Prins (1971, p. 1017) studied the morphological evolution of the Discoaster group and discussed the validity of the name Discoaster as a generic name. Romein (1979) investigated the Early Tertiary discoasters and split them into two groups based on his observations in

LM/CP. Group 1 which includes species without a regular extinction cross and Group 2 which includes species with a regular extinction cross.

Theodoridis (1984, p. 137, 138) emended the diagnosis of the genera Helio-discoaster Tan and Eu-discoaster Tan. Helio-discoaster Tan emended Theodoridis, are discoasters of Palaeogene age with subradial, curved, or hook-shaped sutures and slightly imbricated segments.

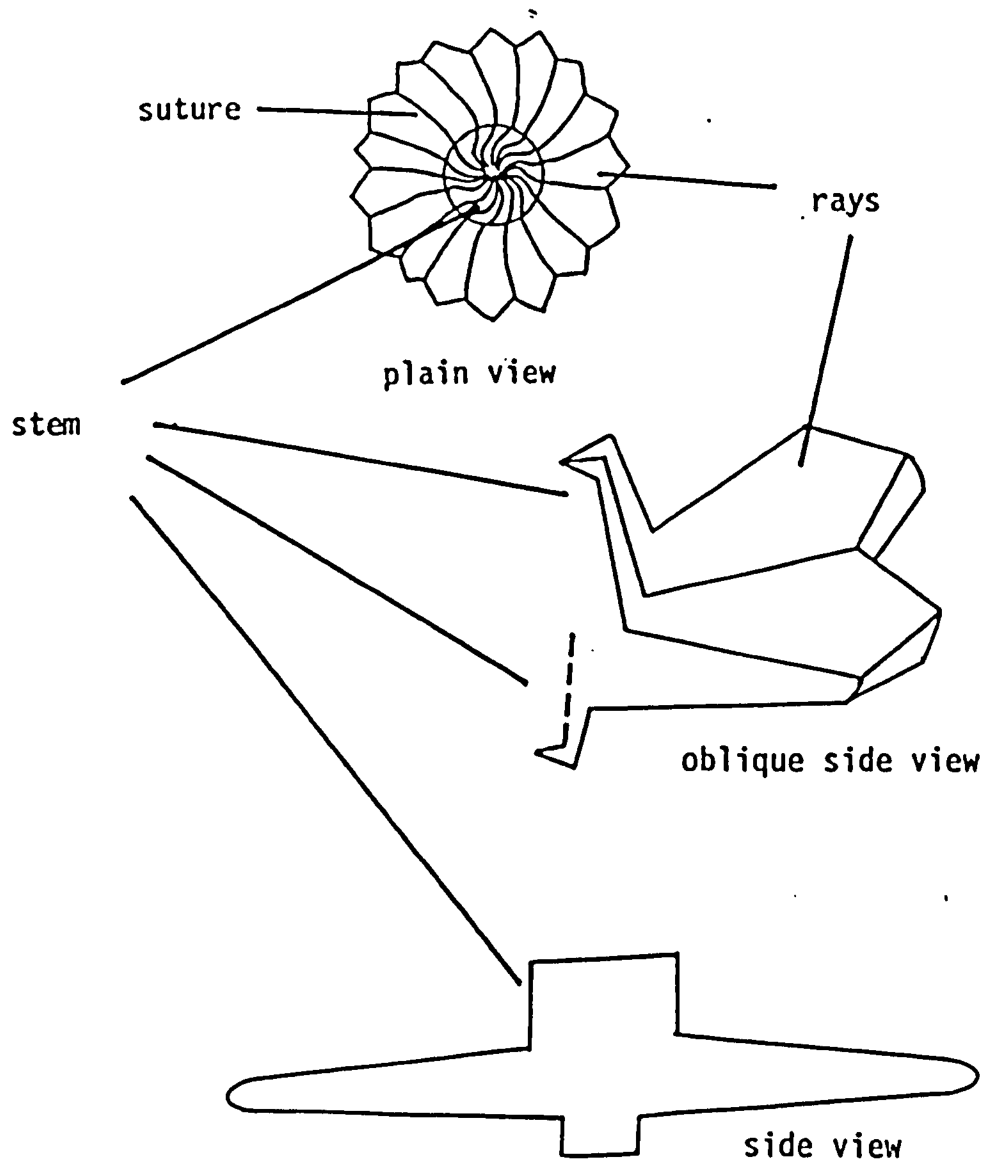


Fig.57 Schematic drawings showing the significant features of the genus Discoaster Tan Sin Hok 1927

Eu-discoaster Tan emended Theodoridis, are discoasters of Neogene age with straight and radial sutures (except for few species appearing in the Eocene).

This classification is not followed in this project because:

1. This work was for investigating Early Tertiary material and there was no time to look at Neogene material.

2. Some discoaster species do not fit the genus Helio-discoaster (e.g. Discoaster mahmoudii, Discoaster okadai).

Discoaster drieveri (Bukry and Percival) Romein

1971 Discoasteroides bramlettei Bukry and Percival, p.129, pl.3, figs.10-12.

1977 Discoasteroides bramlettei Bukry and Percival, Perch-Nielsen, pl.13, figs.6,7.

1978 Heliolithus sp. Perch-Nielsen, Perch-Nielsen et al., pl.14, fig.1.

1978 Discoasteroides bramlettei Bukry and Percival, Perch-Nielsen et al., pl.14, fig.9.

1979 Discoaster bramlettei (Bukry and Percival) Romein, p.159.

1980 Discoaster drieveri (Bukry and Percival) Romein, (INA-Newsletter, vol.2),p.35.

Figured material:

Plate 10, fig.4. UCL-2085-26 Diameter : 5 µm (SEM)

Discoaster atefii n. sp.

Derivation of name: After Atef M.Abdel Baky, my brother.

Diagnosis:

This species is distinguished by its large number of rays and the slightly curved sutures near the centre of the disc on the superior face.

Description:

This species is formed of 20 rays joined through most of their length. In the superior face the sutures between the rays are straight and slightly curved in anticlockwise direction near the centre. The inferior face is more convex and the sutures are straight.

Diameter : 8-10 µm.

Figured Material:

Plate 10, figs. 5-7, UCL-2085-27, 28, 29. (SEM)

Remarks:

This species differs from *D. drieveri* by the absence of the large central stem. *Discoaster mohleri* has fewer rays (9-19) and the sutures between the elements on the superior face are more strongly curved near the centre. *Discoaster multiradiatus* is distinguished from this species by the presence of a stem, the larger number of rays and its shape in side view which is biconvex near the margin and flat near the centre on both sides.

Occurrence: Rare in NP5/6 Zone at Gebel Duwi.

Holotype: Pl. 10, figs. 5-7 (the same specimen in different views), Gebel Duwi, Sample (102).

Type locality: Gebel Duwi, NP5/6 Zone

Age: Late Palaeocene (NP5/6 Zone).

Discoaster duwiensis n. sp.

Derivation of name: After Gebel Duwi, the type locality.

Diagnosis:

This species is distinguished by the presence of an inner cycle of elements on the superior face which is about ⅓ the diameter of the disc.

Description:

This species is formed of 20 to 25 rays joined through most of their length. On the superior face an inner cycle of wedge-shaped elements is present. The number of elements of this inner cycle is about the same as the number of rays. The sutures between the elements of the inner cycle are straight while the sutures between the rays are slightly inclined in an anticlockwise direction. In the centre of the inner cycle a small circular opening is located which may be filled with very tiny elements which extend from the same cycle. On the inferior face the sutures between the rays are straight. This side is more convex than the other one.

Diameter: 6-9 μm.

Figured Material:

Plate 10, figs. 8-9, UCL-2068-14, 15.
Plate 13, fig. 16, UCL-2281-4.

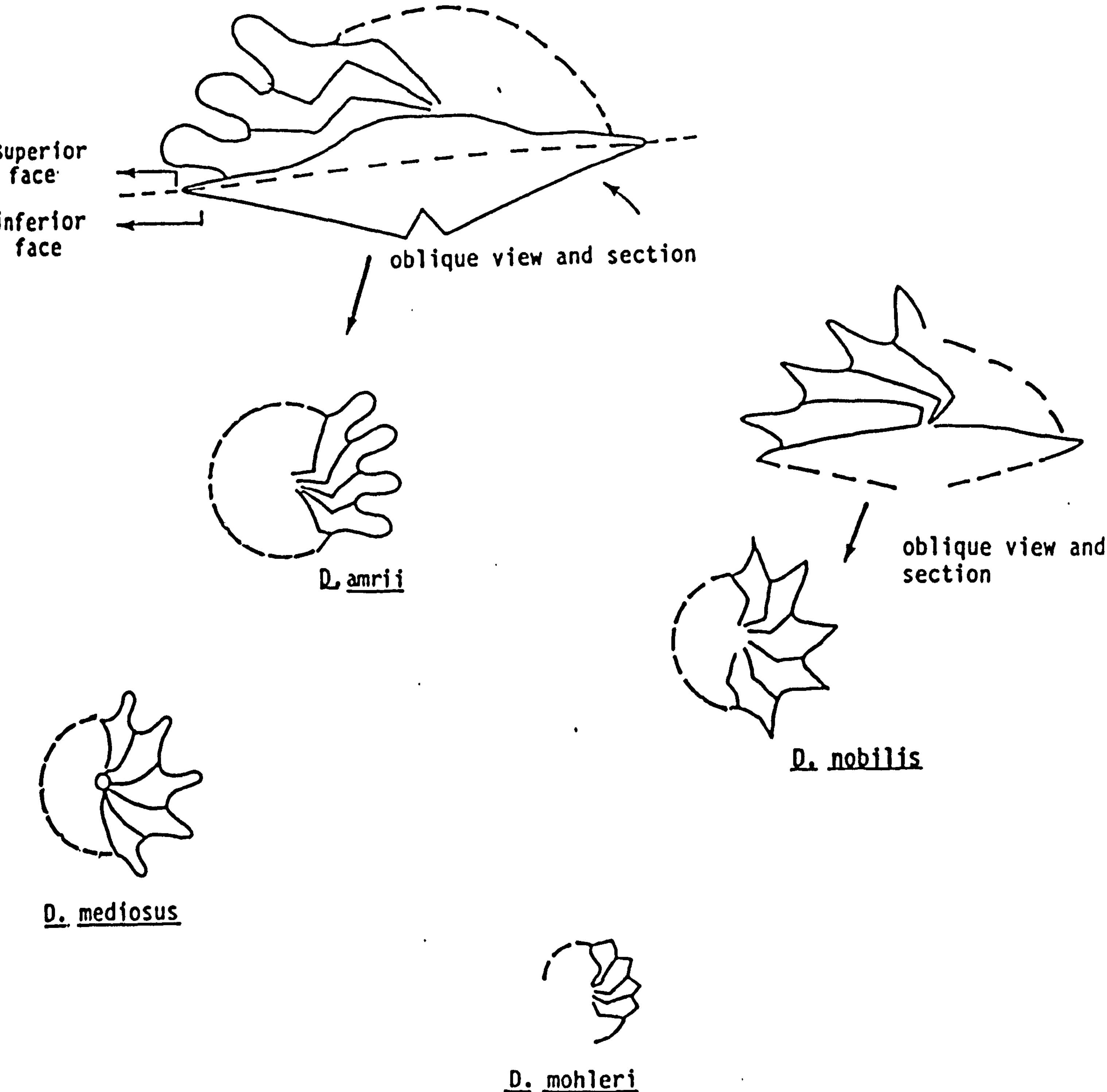


Fig.58–Schematic drawings to illustrate the morphological differences between *Discoaster mohleri*, *D. nobilis*, *D. mediosus*, and *D. amrii*

Remarks:

This species is distinguished from Discoaster atefii by the presence of an inner cycle of elements on the superior face and a central opening. Discoaster drieveri differs from this species by the presence of a stem (column) which is higher and smaller in diameter compared with the inner cycle of this species. Also the stem of D. drieveri is on the inferior face whereas no column or cycles occur on the inferior face of D. duwiensis.

Occurrence:

This species was very rare in the NP5/6 Zone at Gebel Duwi section.

Holotype: Pl. 10, figs. 8-9, (the same specimen in different positions) Gebel Duwi sample (102), NP5/6 Zone.
Type locality: Gebel Duwi, NP5/6 Zone.

Age: Late Palaeocene (NP5/6 Zone).

Discoaster amrii n. sp.

Derivation of name: After Amr M.Abdel Baky, my brother.

Diagnosis:

This species is distinguished by the parallel sided ends of its rays.

Figured Material:
Plate 10, fig.14. UCL-2076-26
fig.15. UCL-1964-10

Description:

This species is biconvex in side view with the inferior face more convex than the superior one. The number of rays are 13 to 16 which join through about half of their length, the free parts of the rays are parallel sided and blunted at their ends. On the superior face the sutures between the rays are hook-shaped or strongly curved near the centre. In inferior face the sutures are straight.

Diameter: 6-10 μm.

Remarks:

This species is distinguished from Discoaster nobilis by its higher number of rays, the presence of parallel sided and blunted ends of its rays, and the central area of the superior face having a cone shape structure while in D. nobilis it is flat near the centre and the rays are pointed at its ends (Fig.58).

Occurrence:

Rare at Gebel Atshan D. multiradiatus Zone (NP9).

Holotype: Pl.10, fig.14, Gebel Atshan, sample (22), NP9 Zone.
Paratype: Pl.10, fig.15, Gebel Atshan, sample (22), NP9 Zone.

Type locality: Gebel Atshan, NP9 Zone.

Age: Late Palaeocene (NP9 Zone).

Discoaster mohleri Bukry and Percival

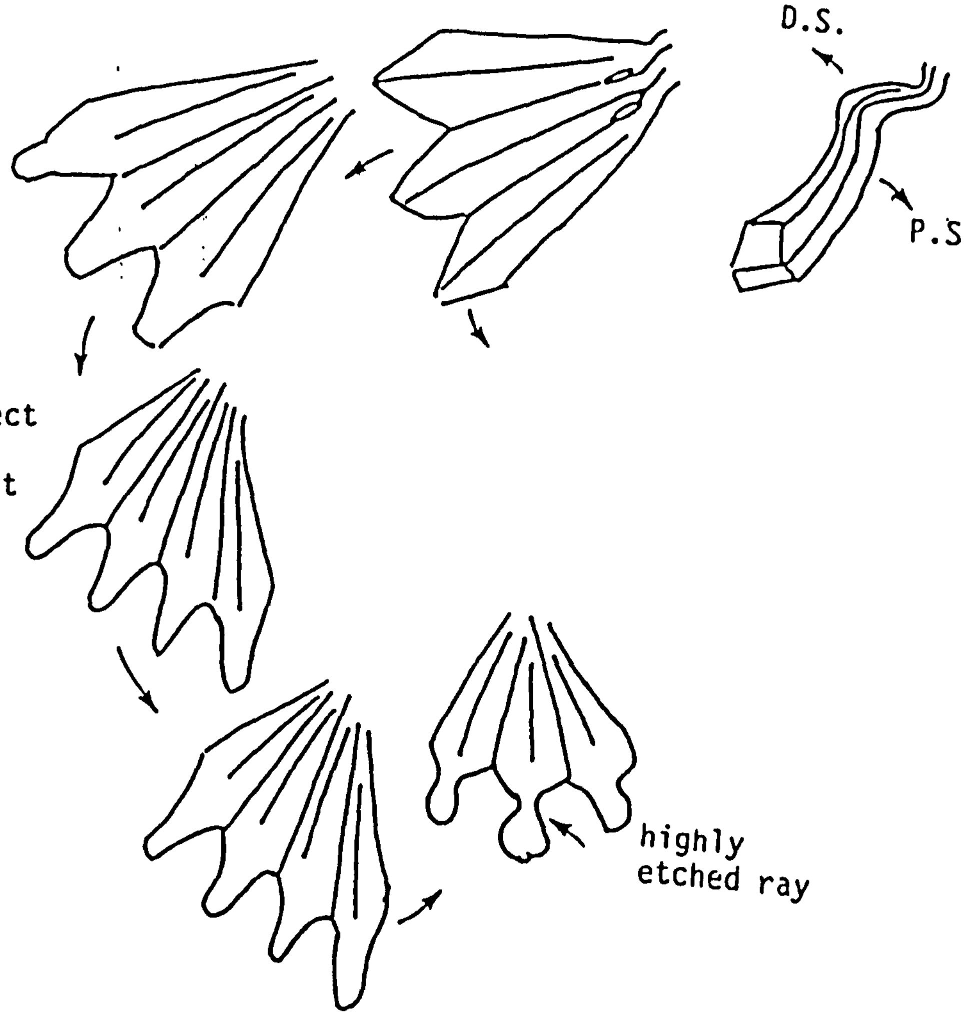


Fig.59 Schematic drawings to illustrate the effect of dissolution on the shape of the outer part of the rays of Discoaster mohleri

1961 Discoaster gemmeus Stradner, in Stradner and Papp, p.77, pl.12, figs.1,2,4,8, test-fig.8/13.

1971 Discoaster mohleri Bukry and Percival, p.128, pl.3, figs.3-5.

1976 Discoaster mohleri Bukry and Percival, Haq and Lohmann, pl.2, figs.1-2.

1978 Discoaster gemmeus Stradner, Perch-Nielsen et al., pl.9, fig.43.

1978 Discoaster gemmeus Stradner, Abdelmalk et al., p.228, pl.4, fig.1.

1983 Discoaster mohleri Bukry and Percival, Varol, p.455, fig.5 (8).

Figured material:

Plate 10, fig.11 UCL-1972-15 Diameter: 7.5 µm (SEM)

Remarks:

This species is biconvex and has from 9 to 19 rays which are joined through most of their length. In inferior face the rays have a median ridge and straight sutures between them. In superior face the sutures between the rays are curved near the centre of this face but straighten out towards the periphery. The superior face is less convex than the other face.

Discoaster mohleri differs from *D. multiradiatus* in

1. the former species has fewer rays than the latter species (16-30 rays).

2. *Discoaster mohleri* is biconvex, while *D. multiradiatus* is flat towards the centre and biconvex away from the centre.

3. the sutures between rays of *D. mohleri* are straight on one side and curved on the other side, while it is straight on both sides of *D. multiradiatus*.

4. the tips at the ends of the rays in *D. mohleri* are rounded or slightly pointed, while it is sharply pointed in *D. multiradiatus*.

5. the rays of *D. mohleri* are broader than the rays of *D. multiradiatus*.

6. *Discoaster multiradiatus* has a knob or stem at the centre, while *D. mohleri* has not.

7. in LM/CP, *D. multiradiatus* shows a regular extinction cross, at the centre while *D. mohleri* does not show this optical character.

Occurrence:

Discoaster mohleri is the zonal marker of D. mohleri Zone (NP7/8). This species is an excellent index species with its wide geographic extinction and short stratigraphic range. The first occurrence of it marks the lower limit of the above mentioned zone. Discoaster mohleri is found in the Lower Tertiary (NP7/8 to NP10) samples investigated during this work. At Gebel Atshan and Wadi Mellaha Sections, D. mohleri and D. multiradiatus first appeared at the same level. The absence of D. mohleri in earlier level most probably due to a gap in sampling and the presence of condensed sequence (about 2 metres represents the Zone NP7/8 from which no samples were collected.

Discoaster mediosus Bramlette and Sullivan

1961 Discoaster mediosus Bramlette and Sullivan, p.161, pl.12, figs.7-8.

1964 Discoaster mediosus Bramlette and Sullivan, Sullivan, p.191, pl.11, fig.13.

1967 Discoaster mediosus Bramlette and Sullivan, Hay and Mohler, p.1539, pl.204, figs.17-18, pl.206, fig.2.

1977 Discoaster mediosus Bramlette and Sullivan, Perch-Nielsen, pl.13, figs.1-2.

Figured material:

Plate 10, fig.12 UCL-1995-14 Diameter: 14.4 μm (SEM)
Plate 13, fig.20 UCL-2279-19

Remarks:

This species is distinguished by the large disc which is terminated by short parallel-sided arms. The gap between every two close arms are forming U-shaped. The tips of the arms are rounded or pointed. The number of arms are from 7 to 11.

Discoaster nobilis Martini

1961 Discoaster nobilis Martini, p.11, pl.2, fig.23; pl.5, fig.51.

1967 Discoaster nobilis Martini, Hay and Mohler, p.1538, pl.204, fig.16, pl.205, figs.6,9.

1976 Discoaster nobilis Martini, Haq and Lohmann, pl.2, fig.7.

1979 Discoaster nobilis Martini, Okada and Thierstein, pl.5, fig.4, pl.15, figs. 6-7.

Figured material:

Plate 10, fig.13, UCL-2051-7 Diameter: 13.3 μm (SEM)
Plate 13, fig.18, UCL-2279-16 (LM)

Remarks:

Discoaster nobilis differs from D. mohleri by

1. the sutures between the rays in the former species are more curved (or hook-shaped) on the superior face than on the same face of the latter species.

2. also the sutures between rays in D. nobilis are more deeply incised than in D. mohleri.

3. in *D. nobilis* the free portions of the rays are longer than those of *D. mohleri*.

Discoaster nobilis differs from *D. mediosus* by:

1. the former species has rays which are ended by long sharply pointed tips, while in the latter species parallel-sided arms end with rounded or slightly pointed tips.

2. in plan view, a U-shape is common between adjacent arms in *D. mediosus*, while it is V-shaped in the case of *D. nobilis*.

3. sutures between rays in *D. nobilis* are more deeply incised than in the case of *D. mediosus*.

Discoaster ornatus Stradner

1958 *Discoaster ornatus* Stradner, p.188, fig.38.

1961 *Discoaster ornatus* Stradner, Stradner and Papp, p.64, pl.2, figs.1-6, text-fig.8/2.

1979 *Discoaster ornatus* Stradner, Romein, p.162.

1984 *Helio-discoaster ornatus* (Stradner) Theodoridis, p.150, pl.31, figs.1-2.

Figured material:

Plate 13, fig.19 UCL-2279-34. (LM)

Remarks:

This species has a few broad rays (most of the specimens consist of 8 rays) with a long pointed free part which is about half of their length. The sutures between the rays are deeply incised. A small knob is present in the centre. Intermediate forms between D. mohleri and D. ornatus are present at the end of the D. mohleri Zone and the D. multiradiatus Zone.

This species differs from D. mohleri by its deeply incised and strongly curved sutures, less number of rays, a longer free part of the rays, broader rays and the presence of a boss in the centre.

Occurrence:

Romein (1979, p. 25, 35) has reported the first occurrance of D. ornatus at the base of the T. contortus Zone NP10 (Early Eocene) at Caravaca Section, Southeast Spain and from an equivalent level at Nahal Avdat Section, Israel. In this work D. ornatus is rare in the top of the D. multiradiatus Zone (Upper Palaeocene) at Wadi Mellaha section. Also it is found in NP10 Zone at Gebel Duwi, Gebel Atshan, Wadi Tarfa and Gebel Tarbouli sections.

Discoaster binodosus Martini

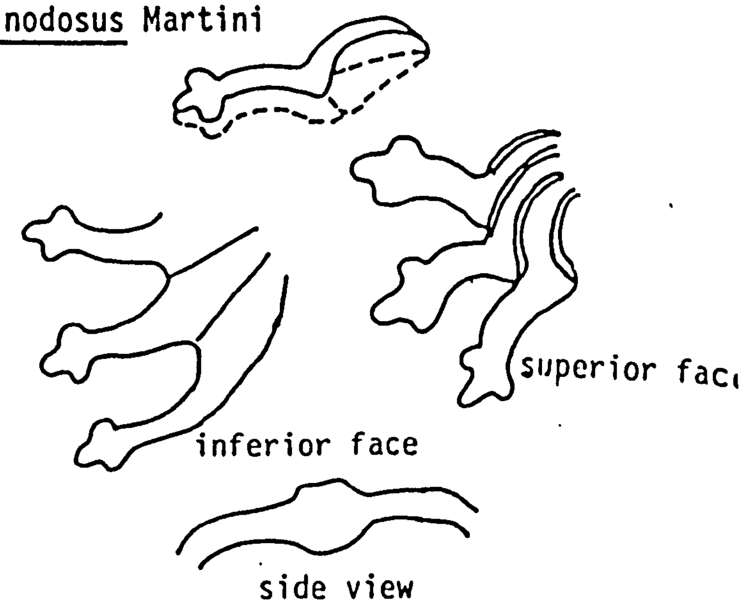


Fig.60 Schematic drawings of the significant features of Discoaster binodosus

1958 Discoaster binodosus Martini, p.361, pl.4, figs.18-19.

1961 Discoaster binodosus Martini, Bramlette and Sullivan, p.158, pl.11, figs.1a-b.

1961 Discoaster binodosus Martini, Stradner and Papp, p.66, pl.4, figs.1-7, pl.5, figs.1-6, text-fig.8/4.

1961 Discoaster binodosus Martini, Stradner and Papp, p.66, pl.4, figs.1-7, pl.5, figs.1-6, text-fig.8/4.

1978 Discoaster binodosus Martini, Perch-Nielsen et al., pl.9, fig.51; pl.13, figs.1, 4, pl.14, figs.7,10,11.

1978 Discoaster binodosus Martini, Abdelmalik et al., p.228, pl.3, figs.11,12.

1981 Discoaster binodosus Martini, Haq and Aubry, pl.7, fig.7.

Figured material:

Plate 11, fig.1 UCL-1903-2 Diameter: 8.5 μm (SEM)
fig.2 UCL-1903-1 Diameter: 7.5 μm (SEM)

Remarks:

Discoaster binodosus is distinguished by the presence of a set of paired nodes near the tip of each arm (Fig.60). Discoaster binodosus consists of 7 to 11 arms. The diameter of the central area and the length of the arms are highly variable. As the diameter of the central area increases the length of the arms decreases and the decorationd (nodes) on the arms is less defined.

The variations in the shape of the tips at the ends of the arms led Martini (1958, p. 362) to split this species into subspecies. Discoaster binodosus binodosus Martini with arms rounded at their tips which first appeared in the Early Eocene and Discoaster binodosus hirundus Martini with arms bifurcated at their tips and first appearance in the Middle Eocene. In this project no specimens are detected with bifurcated arms and all specimens show rounded tips. These specimens are not considered D. binodosus binodosus as the preservational state of the nannofossils for this interval (Early Eocene) in the studied sections is poor to moderately preserved, which may be the reason for the absence of the bifurcated arms.

Occurrence:

Romein (1979, p. 35) has recorded the earliest occurrence of D. binodosus at Nahal Avdat section (Israel) in the D. binodosus Zone NP11 (Early Eocene). Steinmetz and Stradner (1984, p. 690) have recorded this species from NP8 Zone (=upper part of NP7/8, this work) at Hole 530A Site 530, D.S.D.P. (Leg 75) in the Angola Basin in the southeast Atlantic Ocean. In this work D. binodosus is (commonly) found in the T. contortus Zone NP10 (Lower Eocene) at Gebel Tarbouli, Wadi Mellaha and Gebel Atshan sections.

Discoaster multiradiatus Bramlette and Riedel

1954 Discoaster multiradiatus Bramlette and Riedel, p.396, pl.38, fig.10.

1961 Discoaster multiradiatus Bramlette and Riedel, Bramlette and Sullivan, p.161, pl.12, fig.10.

1967 Discoaster multiradiatus Bramlette and Riedel, Hay and Mohler, p.1539, pl.204, fig.22, pl.206, figs.1, 4, 7.

1978 Discoaster multiradiatus Bramlette and Riedel, Perch-Nielsen et al., pl.9, figs.49 - 50, pl.13, figs.5,7,11.

1979 Discoaster multiradiatus Bramlette and Riedel, Okada and Thierstein, pl.5, fig.5, pl.15, figs.8-10.

1979 Discoaster multiradiatus Bramlette and Riedel, Romein, 165, partim, pl.6, figs.1-2, non. pl.6, fig.3.

1984 Helio-discoaster multiradiatus (Bramlette and Riedel) Theodoridis, p.144, pl.28, fig.3.

Figured material:

Plate 11, fig.3 UCL-1995-10 Diameter: 15 μm (SEM)
fig.4 UCL-1964-17 Diameter: 7 μm (SEM)
Plate 13, fig.17 UCL-2279-16 (LM)

Remarks:

This species is biconvex towards its periphery and flat towards the centre (in side view). It is composed of 16 to 30 rays and the margin is serrated.

Romein's specimen (1979, pl. 6, fig. 3) shows a large broken stem in the centre of the disc which is a typical feature for D. salisburgensis Stradner (1961).

Occurrence:

Discoaster multiradiatus is the zonal marker of the D. multiradiatus Zone (Late Palaeocene). Its first occurrence marks the lower limit of the above mentioned zone. It has a wide geographic distribution throughout the Early Tertiary. It is rare to common in the Lower Tertiary (NP9 to NP10) strata investigated throughout this work.

Discoaster lenticularis Bramlette and Sullivan

1961 Discoaster lenticularis Bramlette and Sullivan, p.160, pl.12, figs.1,2.

1964 Discoaster lenticularis Bramlette and Sullivan, Sullivan, p.191, pl.11, fig.1.

1978 Discoaster lenticularis Bramlette and Sullivan, Abdelmalik et al., p.228, pl.4, fig.2.

1979 Discoaster lenticularis Bramlette and Sullivan, Okada and Thierstein, pl.5, fig.2, pl.

1984 Helio-discoaster lenticularis (Bramlette and Sullivan), Theodoridis, p.144.

Remarks:

This is a small astrolithus (compared to the other Early Tertiary discoasters) with a diameter of 6-8 microns. The rare specimens investigated in this project show 18 to 25 rays joined throughout most of their length. This species is more or less biconvex with flat to slightly concave central area. A low and wide central knob is present on one side which shows curved sutures in an anticlockwise direction.

Discoaster diastypus Bramlette and Sullivan

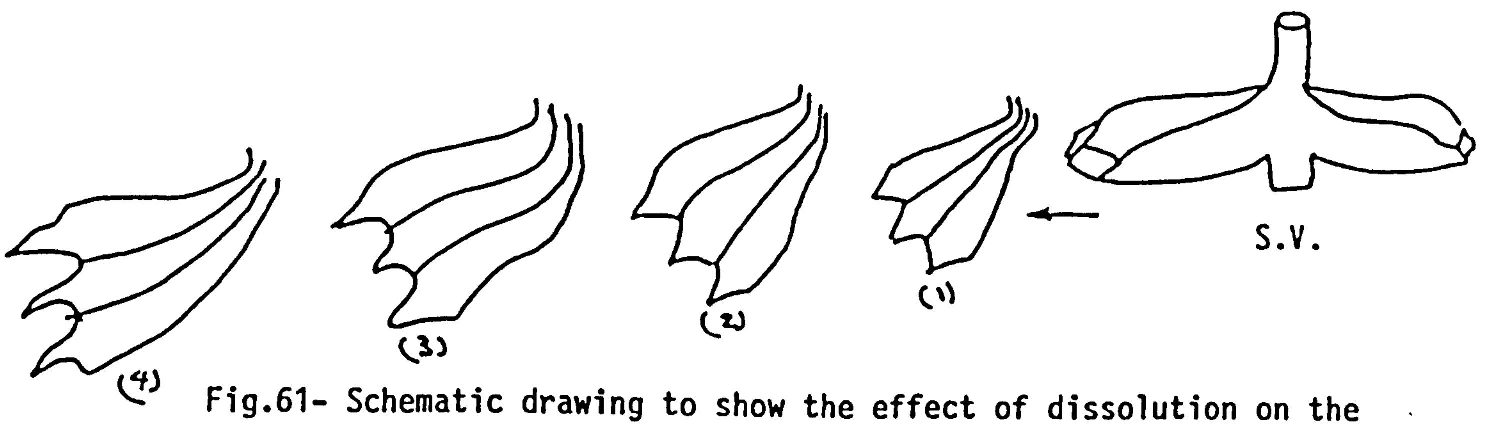


Fig.61- Schematic drawing to show the effect of dissolution on the shape of the outer part of the rays of Discoaster diastypus.

1961 Discoaster diastypus Bramlette and Sullivan, p.159, pl.11, figs.6-8.

1961 Discoaster aff. D. diastypus Bramlette and Sullivan, p.159, pl.11, figs.9-10.

1978 Discoaster diastypus Bramlette and Sullivan, Perch-Nielsen et al., pl.13, figs.2-3, 6.

1978 Discoasteroides kuepperi (Stradner), Abdelmalik et al., p.229, pl.4, fig.9 .

1978 Discoasterides cf. D. megastypus Bramlette and Sullivan, Perch-Nielsen et al. pl.13, fig.10.

1981 Discoaster diastypus Bramlette and Sullivan, Haq and Aubry, pl.7, fig.9.

1982 Discoaster diastypus Bramlette and Sullivan, Hamilton and Hojjatzadah, pl.6.1., fig.11, pl.6.2, fig.8.

1984 Helio-discoaster diastypus (Bramlette and Sullivan) Theodoridis p.145, pl.29, fig.1-3.

Figured material:

Plate 11, fig.5. UCL-2080-17. Diameter: 17.7 μm (SEM)
fig.6. UCL-2084-6. Diameter: 17.7 μm, 13.3μm (two specimens SEM)

Remarks:

Discoaster diastypus consists of 12 to 18 rays and a high central stem at both sides of the disc. The majority of the specimens have a stem which is wider and higher on one side than on the other side, while few specimens have stem on both sides with equal width. The tips of the rays are elongated, sharply pointed and straight or slightly curved in clockwise or anticlockwise direction.

This species differs from D. multiradiatus and D. salisburgensis by the presence of a high stem on both sides, fewer rays and the characteristic elongated sharp tips.

Bramlette and Sullivan (1961) illustrated Discoaster aff. diastypus (pl. 11, figs. 9, 10) and mentioned that it differs from D. diastypus by having rays which are nearly straight rather than curved. Their illustrated specimen (pl. 11, fig. 10) has slightly curved rays and the sutures between the rays in clockwise direction particularly near the periphery. Also most of the tips are curved in clockwise direction.

Their specimens are considered here belong to the *Discoaster diastypus* group as the specimens observed in this study show straight rays which are slightly to strongly curved near their tips.

The specimen illustrated by Perch-Nielsen et al. (1978, pl. 13, fig. 10) as "*Discoasterides* cf. *D. megastypus*" is considered the *D. diastypus* for these reasons:

1. the stem is part of the disc.

2. at the end of the rays the tips are long and pointed a typical feature for *D. diastypus*.

3. this specimen is photographed from the *D. binodosus* Zone (at Gebel Gaurnah, Luxor, South of Egypt) which is above the extinction level of *D. megastypus*.

Discoaster salisburgensis Stradner

1961 *Discoaster salisburgensis* Stradner, p.84, figs. 77, 78.

1962 *Discoaster salisburgensis* Stradner, in Stradner and Papp, p.96, pl.28, fig.3a,b,5.

1971a *Discoaster multiradiatus* Bramlette and Riedel, Perch-Nielsen, Partim, pl.1, fig.5, non pl.1, figs.1,4.

1978 *Discoaster salisburgensis* Stradner, Abdelmalk et al., p.229, pl.4, fig.8.

1978 *Discoaster salisburgensis* Stradner, Perch-Nielsen et al., pl.9, fig.48, pl.13, figs.8-9.

1979 *Discoaster multiradiatus* Bramlette and Riedel, Romein, partim, pl.6, fig.3, non pl.6, figs.1,2.

Figured material:

Plate 11, fig.7 UCL-2073-3 Diameter: 12 µm (SEM)
fig.8 UCL-2073-5 Diameter: 8 µm (SEM)

Remarks:

This species, in side view, is biconvex near the periphery and has a constant width towards the centre and a characteristic wide long stem on one side. The diameter of this stem is about one third to half the diameter of the disc. The number of rays is 18 to 24. The rays are joined along most of their length, with sharply pointed tips.

Discoaster salisburgensis differs from D. multiradiatus by its relatively broader, longer stem and its more biconvex shape in side view.

Discoaster diastypus differs from D. salisburgensis by its longer tapering tips and the presence of a stem in both sides, neither of which is as large in diameter as the diameter of the stem of the latter species.

Specimens illustrated by Perch-Nielsen (1971a) and Romein (1979) as D. multiradiatus (see the synonomy list) are considered to be D. salisburgensis as they show a very wide stem in the centre.

Occurrence:

Discoaster salisburgensis is observed from D. multiradiatus Zone NP9 (Upper Palaeocene) to T. contortus Zone (NP10) at Gebel Duwi and Gebel Atshan sections. Also it is found throughout the Lower Eocene (NP10) at Wadi Mellaha and Gebel Tarbouli sections, also in NP9 Zone at Gebel Um El Ghanayem section.

Discoaster mahmoudii Perch-Nielsen

1981a Discoaster mahmoudii Perch-Nielsen, p.837, pl.4, figs.1-10.

Figured material:

Plate 11, fig.9. UCL-1882-26. Diameter: 12.5 μm (SEM)
Fig.10. UCL-1882-27 Diamete: 9.5 μm (SEM)

Occurrence:

Discoaster mahmoudii is originally described by Perch-Nielsen (1981a) from the D. multiradiatus Zone NP9 (Late Palaeocene) at Gebel Taramsa, Nile Valley, Egypt. As far as I know, this species is not reported from any other area in the world. This may suggest its palaeogeographic limitation. During this work D. mahmoudii is found at the base of the T. contortus Zone NP10 (Lower Eocene) at Wadi Mellaha, Wadi Tarfa, and Gebel Tarbouli sections, in the D. multiradiatus Zone NP9 (Upper Palaeocene) at Gebel Um El Ghanayem section and from the top of the D. multiradiatus Zone to the base of the T. contortus Zone (Lower Eocene) at Gebel Duwi section.

Discoaster okadai Bukry

1971 Turbodiscoaster sp.1 Prins, p.1023, pl.4, fig.23.

1981 Discoaster okadai Bukry, p.461, pl.1, figs.5-11; pl.2, figs.1-6.

1984 Discoaster okadai Bukry, Steinmetz and Stradner, pl.38, figs.1-6, pl.39, figs.1-4; pl.40, figs.1-3.

Figured material:

Plate 11, fig. 11. UCL-1972-10 Diameter: 8.5 µm (SEM)

Remarks:

Asterolith with 4 to 6 rays. The rays are free along most of their length, long and with more or less rounded tips. The sutures between the rays are straight and deeply incised on both sides. Few specimens show thin rays with broad tips. No central knob is present.

This species is distinguished from D. binodosus by its straight sutures on both sides and the lower number of rays.

Occurrence:

Discoaster okadai is found (rare) in the D. multiradiatus Zone (NP9) at Gebel Atshan, Wadi Tarfa, and Wadi Mellaha sections.

Family: PONTOSPHAERACEAE Lemmerman 1908
Genus Pontosphaera Lohmann 1902
Type species Pontosphaera syracusana Lohmann 1902

Pontosphaera versa (Bramlette and Sullivan) Romein

1961 Discolithus versus Bramlette and Sullivan, p. 144, pl.3, figs.16a-d.

1979 Pontosphaera versa (Bramlette and Sullivan) Romein, p.176.

Figured material:

Plate 11, fig.12. UCL-2081-8 Length: 13.3 µm (SEM)

Remarks:

This species has a high rim and a thin basal plate bisected by a narrow elongated opening parallel to the long axis of the ellipse.

Pontosphaera versa differs from Pontosphaera plana (Bramlette and Sullivan), Haq by the presence of a thickned rim and thinner plate than in the latter species.

Occurrence:

Pontosphaera versa is found in the D. multiradiatus Zone (NP9) at Gebel Um El Ghanayem section. It is recorded at Gebel Tarbouli from NP10 Zone (Early Eocene) and at Wadi Mellaha section from the top of NP9 Zone and NP10 Zone.

Pontosphaera exilis (Bramlette and Sullivan) Romein,

1961 Discolithus exilis Bramlette and Sullivan, p.142, pl.2, figs.10a-c.

1979 Pontosphaera exilis (Bramlette and Sullivan) Romein, p.179.

Figured material:

Plate 11, fig.13. UCL-2084-5 Length: 8 μm (SEM)

Remarks:

This species is distinguished by a thin and high rim attached to a central plate with two large openings.

Occurrence:

Pontosphaera exilis is found rarely in Wadi Mellaha and Gebel Tarbouli Section in the NP10 Zone (Early Eocene).

CHAPTER VII

SUMMARY AND CONCLUSIONS

A field study was carried out in 1983 & 1984 of the uppermost Cretaceous and Early Tertiary deposits of different areas of northern and central Egypt. In this study 7 surface sections were measured and sampled, from the Wadi Tarfa, Esh Mellaha, Quseir and Kharga areas. A detailed study of the calcareous nannofossils of these sections was subsequently carried out. The assemblages have been examined with the aid of both the light microscope (using transmitted light, phase contrast and cross polarizers) for general investigation and observations and the scanning electron microscope for determination of the surface structure. Two methods of preparation were used for the light microscope study: soaked smear slides gave a more or less accurate impression of the composition of the assemblages and the relative abundance of each species, while the centrifuging method was used for detailed study and SEM work with clean material. An abundant calcareous nannoflora with generally high diversity was found. Mainly moderately preserved assemblages with a few well-preserved assemblages at intervals were found in the Maastrichtian strata. Poorly to moderately preserved assemblages affected by dissolution were observed in the Lower Tertiary. This work thus includes biozonation, biostratigraphy, preservation, evolutionary lineages, palaeocology, and taxonomy of the calcareous nannofossils.

The calcareous nannofossil zonation spanning the interval Maastrichtian-Early Eocene used in this study is based upon local ranges and was compared with the zones proposed by Martini (1971), Sissingh (1977), Verbeek (1977) and Romein (1979). A new zone the *Fasciculithus ragaae* Zone is described. This zone occurs in the early Thanetian at the Gebel Duwi, Gebel Atshan, Wadi Tarfa, Gebel Um El Ghanayem and Wadi Tarfa sections.

The upper boundary of the Ellipsolithus macellus Zone of Martini (1971) is emended so as to be marked by the first occurrence of Fasciculithus ragaae (the first occurrence of this species marks the lower boundary of the Fasciculithus ragaae Zone). Also, the upper boundary of the Fasciculithus tympaniformis Zone of Mohler and Hay (1967) is emended to coincide with the first occurrence of Discoaster mohleri. The calcareous nannofossil zones used in this work are:

11.	Tribrachiatus contortus Zone (NP10)	"early" Ypresian
10.	Discoaster multiradiatus Zone (NP9)	"late" Thanetian
9.	Discoaster mohleri Zone (NP6/7)	"early" Thanetian
8.	Fasciculithus tympaniformis Zone (NP5/6)	Selandian - Thanetian
7.	Fasciculithus ragaae Zone (NP4b)	"middle" Selandian
6.	Ellipsolithus macellus Zone (NP4a)	"early" Selandian
5.	Chiasmolithus danicus Zone (NP3)	Danian

GAP

4.	Nephrolithus frequens Zone	Late Maastrichtian
3.	Lithraphidites quadratus Zone	Early-Late Maastrichtian
2.	Arkhangelskiella cymbiformis Zone	Early-Late Maastrichtian
1.	Quadrum trifidum Zone	Late Campanian-Early Maastrichtian

Study of the stratigraphic ranges of the nannofossils provided many good marker species, in addition to the zonal markers. The extinction levels of Quadrum gartneri, Q. gothicum and Q. sissinghii mark the upper limit of Q. trifidum Zone. The extinction levels of Glaukolithus compactus, Reinhardtites levis, Tranolithus orionatus and Broinsonia parca mark the lower part of the A. cymbiformis Zone. The extinction level of Cruciplacolithus edwardsii marks the upper limit of the NP3 Zone. The extinction level of Chiasmolithus danicus falls within the lower part of NP4b Zone and is a useful datum. Fasciculithus ulii is a useful stratigraphic marker, its first appearance is in the upper part of NP4a Zone and its extinction level is in the lower part of NP5/6 Zone. The first appearances of Camphylosphaera dela, Discoaster salisburgensis, D. mahmoudii and Chiasmolithus californicus mark the lower part of NP9 Zone. The extinction level of Cruciplacolithus tenuis and the first appearances of Discoaster diastypus and D. ornatus mark the upper part of the NP9 Zone. The lower limit of the NP10 Zone is marked by the first appearance of *Discoaster binodosus*.

At the Cretaceous-Tertiary boundary there is an abrupt change in the nannoflora, with extinctions and the appearances of new flora. The uppermost Maastrichtian and the Lower Danian are missing in the studied sections so the abrupt change is a reflection of this hiatus. No lithologic change was observed at or near this boundary in the Gebel Tarbouli and Wadi Mellaha sections but the sequences are not continuous. The Lower Palaeocene zones are probably present at Esh Mellaha within a thin sequence of sediments which was not sampled. At Wadi Tarfa the boundary is marked by a change in lithology from chalk of Maastrichtian age to shale of Palaeocene age with a time gap. A conglomeratic band (1m) is found at the top of the Maastrichtian sediments (lower part of Dakhla Shale) at Gebel Um El Ghanayem. At Gebel Duwi, a thin bed of non-calcareous black shale (1.5m) is found above marl of the lower part of Dakhla Shale Formation of Maastrichian age and is itself overlain by marls of the upper part of the Dakhla Shale Formation of Palaeocene age. The presence of black shale at the Cretaceous-Tertiary boundary at Gebel Duwi and in the Maastrichtian of Gebel Um El Ghanayem reflects reduced oxygen levels in the depositional environment in these areas at that time. These two areas formed separate basins at the end of the Cretaceous during a major regional regression.

The absence of some zones within the Palaeocene strata examined in this work is probably due to them being missed during sampling (as no interruption in the rock sequence was observed in the section), hence closer spaced samples need to be taken in future work.

The nannofossil assemblages of the *Q. trifidum* Zone (Late Campanian-Early Maastrichtian) at Gebel Tarbouli and Wadi Tarfa indicate warm shallow marine conditions. In the *A. cymbiformis* Zone and *L. quadratus* Zone at Esh Mellaha, Quseir and Wadi Tarfa areas a warm, more open marine inner to outer shelf, stable environment was present. The nannofloral assemblages of Early Palaeocene indicate a warm, open marine environment. In the Late Palaeocene and Early Eocene the assemblages indicate a warm, more open marine condition than in the Early Palaeocene.

One hundred and sixty species have been identified. The new family RHOMBOASTERACEAE is proposed for Late Palaeocene-Early Eocene genera which consist of a single calcite unit and have the form of a rhombohedron with tri-and hexaradiate shape. One new genus Diadochiastozygus is created for forms previously assigned to Neochiastozygus, which differ in having a vertical outer rim. Five new species are described, Fasciculithus ragaae, F. gelelii, Discoaster atefii, D. duwiensis and D. amrii. New combinations of Bomolithus megastypus, B. kleinpellii and B. cantabriae are included. These species are transferred from the Genus Heliolithus to Bomolithus because the type species of the former, H. riedelii, is constructed of two cycles of elements while the type species of Bomolithus is composed of three. The known stratigraphic ranges of many species are modified for the Egypt area.

Evolutionary lineages recognised by other nannoflora specialists were compared with my material. A number of new observations are made:

1. Lineages in the genus Micula, particularly for the youngest members M. murus and M. prinsii were analysed. A small ancestral form for M. murus (called Micula sp.) and intermediates between M. murus and M. prinsii were recognised.

2. Measurement of the length-width ratio for the Lithraphidites group was carried out on Gebel Tarbouli material, which showed changes in dimensions from L. carniolensis to L. quadratus through the Maastrichtian. In addition, the number of specimens of L. quadratus and L. praequadratus increases in progressively younger assemblages in the Late Maastrichtian.

3. In lineages of the genera Cruciplacolithus and Campylosphaera, Cruciplacolithus frequens is considered to have evolved from C. tenuis in the lower part of NP5/6 (not in the NP7/8 as mentioned by Romein 1979, p. 58, 64) and Campylosphaera dela evolved from C. tenuis in the lower part of NP9.

4. In the genus Ericsonia, E. subpertusa is considered to be the ancestor of Ericsonia sp. A, and E. robusta evolved from E. subpertusa in the lower part of NP5/6 which is earlier than previously recognised.

5. In the genus Chiasmolithus, C. danicus is considered to be the ancestor of C. consuetus. The changes in the orientation of the central crossbars in the devolpment of C. eograndis from C. bidens is explained (with schematic drawings) according to my observations on these species in the Gebel Atshan section.

6. In the Neochiastozygus group, N. junctus involved from N. perfectus in the lower part of NP9. Measurements of length and the angles between the crossbars of the central area and the major axes of the ellipse in specimens of N. perfectus and N. junctus has been carried out from three sections. The biometrics show increase of length in progressively younger assemblages.

7. In the Fasciculithus group, F. ragaae n. sp. evolved from F. ulii and is considered to be the ancestor of F. gelelii n. sp.. A new explanation of the origin of F. billii, F. janii, F. involutus and F. alanii was presented.

8. In the Bomolithus group, B. elegans is considered to be the ancestor of B. megastypus. This is based on measurements of the diameters of the median cycle and the column of specimens from Gebel Duwi.

9. In the Discoaster group, the ancestor of D. mohleri is probably one of three eary Discoaster species: D. drieveri, D. atefii n. sp. or D. duwiensis n. sp.. The origin of D. multiradiatus and D. binodosus is discussed. Discoaster salisburgensis and D. amrii n. sp. are incorporated in the postulated lineages of the Discoaster group. The origins of D. mahmoudii and D. okadai remain unknown.

CHAPTER VIII

REFERENCES

ABDELMALIK, W.M., BASSIOUNI, M.A., KERDANY, M.T. and OBEID, F. L. (1978). - Biostratigraphy of Upper Cretaceous - Lower Tertiary rocks from West Central Sinai. 2. Calcareous Nannoplankton. Ann. Min. Geol., Tunis, 28, Actes du Vle Colloque Africain de Micropaleontologie, Tunis 1974, Tome 2, pp. 217-241.

ARKHANGELSKY, A.D. (1912): Upper Cretaceous deposits of East European Russia. Mater. Geol. Russ., 25, pp.1-631.

ARKIN, Y., NATHAN, Y. and STARINSKY, A. (1972). Paleocene - Early Eocene environments of deposition in the Northern Negev (Southern Israel). Geol. Surv. Israel Bull., 56, pp. 1-18.

AUBRY, M.P. (1983). Biostratigraphie du Paléogène épicontinental de l'Europe du Nord-Ouest. Étude fondée sur les nannofossiles calcaires. Docum. Lab. Géol. Lyon, 89, pp.1-317.

AWAD, G.H., (1964). Palaeontological zoning of the Upper Cretaceous - Lower Tertiary in the U.A.R. Geol. Soc. of Egypt, Second annual meeting, Cairo, May 1964.

AWAD, G.H. and GHOBRIAL, M.B. (1965). Zonal stratigraphy of Kharga Oasis. Gen. Egypt. Org. Geol. Res. Min., Geol. Surv., 34, pp.1-77.

AWAD, G.H. and ABDELLAH, A. M. (1966). Upper Cretaceous in southern Galala, Eastern Desert, with emphasis on neighbouring area. J. Geol. U.A.R., 10, No.2, pp. 125-144.

BÁLDI-BEKE, M. (1984). A dunantuli paleogen Kepzodmenyek nannoplanktonja. (The nannoplankton of the Transdanubian Palaeogene formations). Geologica Hungarica, Series Palaeontologica, 43, pp.1-307.

BALL, J. (1900). Kharga Oasis, its topography and geology, Egypt. Survey Dept., Cairo, pp.1-116.

BERGGREN, W. A., KENT, D. V. and FLYNN, J. F. (1985). Paleogene geochronology and chronostratigraphy. In: Snelling N. J. (ed.), The Chronology of the Geological Record (Part 2). Blackwell Scientific Publications, pp. 141-177.

BLACK, M. (1964). Cretaceous and Tertiary coccoliths from Atlantic seamounts. Palaeontology, **7**, no.2, pp. 306-316.

BLACK, M. (1965). Coccoliths. Endeavour, **24**, no.93, pp. 131-137.

BLACK, M. (1967). New names for some coccolith taxa. Proceedings of the Geological Society of London, **1640**, pp. 139-145.

BLACK, M. (1968). Taxonomic problems in the study of coccoliths, Palaeontology, **11**, pp. 793-813.

BLACK, M. (1971). Coccoliths of the Speeton Clay and Sutterby Marl. Proceedings of the Yorkshire Geological Society, **38**, pp.381-424.

BLACK, M. (1975). British Lower Cretaceous Coccoliths 1. Gault Clay. Palaeontogr. Soc. Monogr. III, **129**, pp. 113-142.

BLACK, M. and BARNES, B. (1959). The structure of coccoliths from the English Chalk. Geol. Mag., **96**, pp. 321-328.

BOUDREAUX, J.E. and HAY, W.W. (1969). Calcareous nannoplankton and biostratigraphy of the Late Pliocene-Pleistocene-Recent sediments in the submarex cores. Revista Esp. Micropal., **1**, pp.249-292.

BRAARUD, T. et. al. (1964). <u>Rhabdosphaera</u> Haeckel, 1894 (Coccolithophorida) proposed validation under the plenary power and designation of a lectotype for <u>Coccolithus</u> <u>oceanicus</u> Schwarz, 1894. Bull. Zool. Nomencl., **21**, pp.379-400.

BRAMLETTE, M.N. and RIEDEL, W.R. (1954). Stratigraphic value of discoasters and some other microfossils related to Recent coccolithophores. J. Paleont., 28, pp. 385-402.

BRAMLETTE, M.N. and SULLIVAN, F. R. (1961). Coccolithophorids and related Nannoplankton of the early Tertiary in California. Micropal., 7, no. 2, pp. 129-188.

BRAMLETTE, M.N. and MARTINI, E. (1964). The great change in calcareous nannoplankton fossils between the Maastrichtian and Danian. Micropal., 10, no. 3, pp. 291-322.

BRAMLETTE, M.N. and WILCOXON, J. A. (1967). Middle Tertiary calcareous nannoplankton of the Cipero section, Trinidad, W.I. Tulane Studies Geol. Paleont., 5, pp.93-131.

BRONNIMANN, P. and STRADNER, H. (1960). Die Foraminiferen-und Discoasteriden zonen von Kuba und ihre interkontinentale korrelation. Erdol-Z., 76, pp. 364-369.

BROTZEN, F. (1959). On Tylocidaris species (Echinoidea) and the stratigraphy of the Danian of Sweden. Sveriges Geol. Undersokn., C., pp.1-571.

BUKRY, D. (1969). Upper Cretaceous coccoliths from Texas and Europe. Univ. Kansas Paleont. Contrib., Art. 51, (Protista 2), pp. 1-79.

BUKRY, D. (1971). Discoaster evolutionary trends. Micropal., vol. 17, pp. 43-52.

BUKRY, D. (1972). Further comments on Coccolith stratigraphy, leg. 12, Deep Sea Drilling Project. In Laughton A.S. et al., Initial Reports of the Deep Sea Dilling Project, Washington D.C. (U.S. Government Pringing Office), 12, pp.1071-1083.

BUKRY, D. (1973a). Low-latitude coccolith biostratigraphic zonation. In Edger N.T., Saunders J.B. et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), 15, pp. 685-703.

BUKRY, D. (1973b). Coccolith stratigraphy, Eastern equatorial Pacific, leg. 16, Deep Sea Drilling Project. In Van Andel, T.H., Heath, G.R. et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), 16, pp. 653-711.

BUKRY, D. (1981). Pacific coast coccolith stratigraphy between point conception and Cabo corrientes, Deep Sea Drilling Project, leg 63. In Yeats, R. S., Haq, B.S. et al., Initial Reports of the Deep sea Drilling Project. Washing (U.S. Government Printing Office), 63, pp.445-471.

BUKRY, D. and BRAMLETTE, M.N. (1969). Some new and stratigraphically useful calcareous nannofossils of the Cenozoic. Tulane Studies Geol. Paleont., 7, 131, pp. 131-142.

BUKRY, D. and BRAMLETTE, M.N. (1970). Coccolith age determinations, Leg 3, Deep Sea Drilling Project. In Maxwell, A., et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), 3, pp.589-611.

BUKRY, D. and PERCIVAL, S.F. (1971). New Tertiary calcareous nannofossils. Tulane Studies Geol. Paleont., 8, pp. 123-146.

CARATINI, C. (1963). Contribution a l'etude des coccolithes du Cenomanian superieur et du Turonian de la region de Rouen. Universite d'Alger, These, pp.1-61, (Published 1963, thesis dated 1960).

CEPEK, P. (1970). Zur Vertikalverbreitung von coccolithen - Arten in der oberkreide NW - Deutschlands. Geol. jahrbuch, Hannover, 88, pp.235-264.

CEPEK, P. and HAY, W. (1969a). Calcareous nannoplankton and biostratigraphic subdivision of the Upper Cretaceous. Trans. Gulf Coast Assoc. Geol. Soc., 19, pp. 323-336.

CEPEK, P. and HAY, W. (1969b). Zonation of the Upper Cretaceous using calcareous nannoplankton. XXIII Internat. Geol. Congr. (Prague), Proc. Paleobot. Sect., pp. 333-340.

CHRISTENSEN, T. (1962). Botanik, Bind II : Systematisk Botanik, Nr. 2, Alger. Munksgaard, Copenhagen, pp.1-178.

CRUX, J.A. (1981). New calcareous nannofossil taxa from the Cretaceous of South East England. Neues Jahrbuch fur Geologie und Palaontologie, Monatshefte 1981, pp. 633-640.

CRUX, J.A. (1982). Upper Cretaceous (Cenomanian to Campanian) calcareous nannofossils. In: Lord A.R. (ed.), A Stratigraphic Index of Calcareous Nannofossils. Ellis Horwood Ltd., Chichester, pp. 81-135.

DEFLANDRE, G. (1939). Les stephanolithes, representants d'un type nouveau de coccolithes du Jurassique superieur. C.R. Acad. Sci, Paris, 208, pp.1331-1333.

DEFLANDRE, G. (1947). Braarudosphaera nov. gen., type d'une famille nouvelle de Coccolithophorides actuels a elements composites. C.R. Acad. Sc., Paris, 225, pp. 439-441.

DEFLANDRE, G. (1950). Observations sur les Coccolithophorides, a propos d'un nouveau type de Braarudosphaeride, Micrantholitus a elements clastiques. C.R. Acad. Sci., Paris, 331, pp. 1156-1158.

DEFLANDRE, G. (1952a). Classe des Cocclithophorides (Coccolithophoridae Lohmann, 1902). In Grasse, P.P., Traite de Zoologie, 1, pp.439-470.

DEFLANDRE, G. (1952b). Classe des Coccolithophorides. In Piveteau, J, Traite de Paleontologie, 1, pp. 107-115.

DEFLANDRE, G. (1953). Hétérogénité-intrinséque et pluralité des éléments dans les coccolithes actuels et fossiles. C.R. Acad. Sci., Paris, **237**, pp.1785-1787.

DEFLANDRE, G. (1959). Sur les nannofossiles calcaires et leur systematique. Rev. Micropal., 2, no. 3, pp. 127-152.

DEFLANDRE, G. (1963). Sur les Microrhabdulidés, famille nouvelle de nannofossiles calcaires. C.R. Acad. Sci., Paris, **256**, pp.3484-3486.

DEFLANDRE, G., and FERT, C. (1954). Observations sur les Coccolithophoridés actuels et fossiles en microscope ordinaire et electronique. Ann. Paléont., **40**, pp. 115-176.

DOEVEN, P.H. (1983). Cretaceous nannofossil stratigraphy and paleoecology of the Canadian Atlantic margin, Geological Survey of Canada Bulletin, **356**, pp. 1-70.

EDWARDS, A.R. (1963). A preparation technique for calcareous nannoplankton. Micropl., **9**, pp.103-104.

EDWARDS, A.R. (1971). A calcareous nannoplankton zonation of the New Zealand Paleogene. In Farinacci, A. (ed.), Proc. Second Plankt. Conf., Roma 1970, pp. 381-419.

EDWARDS, A.R. (1973). Key species of the New-Zealand calcareous Nannofossils. New Zealand Journ. Geol. and Geoph., **16**, no. 1, pp. 68-89.

EDWARDS, A.R. and PERCH-NIELSEN, K. (1975). Calcareous Nannofossils from the Southern South west Pacific, Deep Sea Drilling Project, Leg 29. In Kennett J.P.m, Houtz, R.E. et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), **29**, pp. 469-539.

EHRENBERG, C.G. (1836). Uber mikroskopische neue Chacaktere der erdigen und derben Mineralien. Ann. Phys. U. Chem., **39**, pp. 101-106.

EL-DAWOODY, A.S. and BARAKAT, M.G. (1973). Nannobiostratigraphy of the Upper Cretaceous/Paleocene contact in Duwi Range, Quseir District, Egypt. Riv. Ital. Paleont. e Strat., **79**, no. 1, pp. 103-124.

EL-DAWOODY, A.S. and ZIDAN, M.A. (1976). Micro and nannopaleontology of the Upper Cretaceous-Paleocene succession in West Mawhoob area, Dakhla Oasis, Egypt. Rev. Esp. de Micropal., **XIII**, No.3, pp.401-428.

FARIS, M. (1984). The Cretaceous/Tertiary boundary in Central Egypt (Duwi region, Nile Valley, Kharga and Dakhla Oasis) - N. jb. Geol. Palaont. Mh., Stuttgart, **7**, pp.385-392.

FARIS, M. (1985). Stratigraphy of the Late Cretaceous-Early Tertiary sediments in the Ghanima and Ain Amur sections, Kharga area, Egypt, Newsl. Stratigr., **14**, no. 1, pp.36-47.

FORCHHEIMER, S. (1972). Scanning electron microscope studies of Cretaceous coccoliths from the Kopingsberg Borehole no. 1, S.E. Sweden. Sveriges Geologiska Undersokning, Ser. C, 668, Arsbok **65**, No. 14, pp. 1-141.

FRITSCH F.E. (1929). Evolutionary sequence and affinities among protophyta. Reprint from Biological Review, **4** **(2)**, April 1929.

FUTTERER, D. (1976). Calcareous dinoflagellates (Calciodineiloideae) and the taxonomic position of the Thoracosphaheroideae. N. Jb. Geol. Palaont. Abh., **151**, 2, pp.119-141.

GARDET, M. (1955). Contribution à l'étude des coccolithes des terrains Néogènes de l'Algerie. Publications du Service de la Carte Géologique de l'Algérie, Series 2, 5, pp. 477-550.

GARTNER, S. (1968). Coccoliths and related calcareous nannofossils from Upper Cretaceous deposits of Texas and Arkansas. Univ. Kansas Paleont. Contrib.-Protista, Art. 1, pp.1-56.

GARTNER, S. (1970). Phylogenetic lineages in the Lower Tertiary coccolith genus Chiasmolithus. Proc. N. Am. Pal. Conv., 1969, Part G, pp. 930-957.

GARTNER, S. (1971). Calcareous nannofossils from the JOIDES Black Plateau cores, and revision of Paleogene nannofossils zonation. Tulane Studies Geol. Pal., 8, pp. 101-121.

GARTNER, S. (1977). Nannofossils and biostratigraphy, an overview. Earth. Sci. Rev., 13, pp. 227-250.

GARTNER, S. and KEANY, J. (1978). The terminal Cretaceous event, a geological problem with an oceanographic solution. Geology, 6, pp.708-712.

GHOBRIAL, M.G. (1967). The Structural Geology of the Kharga Oasis. General Egyptian Organisation for Geological Research and Mining, Geological Survey, 43, pp.1-39.

GÓRKA, H. (1957). Les coccolithophoridés du Maestrichtien supérieur de Pologne. Acta Palaeont. Polon., 2, pp. 235-284,

GRAN, H.H. and BRAARUD, T. (1935). A quantitative study of the phytoplankton in the Bay of Fundy and the Gulf of Maine. J. Biol. Board Canada, 1, pp. 279-467.

GRUN, W. and ALLEMANN, F. (1975). The Lower Cretaceous of Caravaca (Spain); Berriasian calcareous nannoplankton of the Miravetes Section (subbetic Zone, Prov. of Murcia). Eclogae Geol. Helv., 68, pp. 147-211.

HAMILTON G.B. and HOJJATZADAH M. (1982). Cenozoic calcareous nannofossils a reconnaissance. In: Lord A.R. (ed.), A Stratigraphic Index of Calcareous Nannofossils. Ellis Horwood Ltd., Chichester, pp. 136-173.

HAQ, B. (1971). Paleogene calcareous nannoflora. Part I: The Paleocene of West-Central Persia and the Upper Paleocene-Eocene of West Pakistan. Stockh. Contr. Geol., 25, pp.1-56.

HAQ, B. and LOHMANN, G.P. (1976). Early Cenozoic calcareous nannoplankton biogeography of the Atlantic Ocean. Marine Micropal., 1, no.2, pp. 119-194.

HAQ, B. and AUBRY, M. P. (1981). Early Cenozoic calcareous nannoplankton biostratigraphy and paleobiogeography of North Africa and the Middle East and Trans-Tethyan correlations. In salem N.N. et al. (eds.), The Geology of Lybia. Academic Press, New York, pp. 271-304.

HARLAND, W. B., COX, A. V., LLEWELLYN, P. G., PICKTON, C.A. G., SMITH, A.G. and WALTERS, R. (1982). A geologic time scale. In Cook A.H., Harland, N.F. et al. (eds.). Cambridge Earth Science Series. Cambridge Universithy Press, Cambridge, pp.1-131.

HATTNER, J.G. and WISE, J.R. (1980). Upper Cretaceous calcareous nannofossil biostratigraphy of South Carolina. South Carolina Geol., 24, no. 2, pp. 44-117.

HAY, W. W. (1964). Utilisation stratigraphique des Discoastérides pour les zones du Paléocéne et de l'Eocène inférieur. Mem. B.R.G.M., 28, pp. 885-889.

HAY, W. W. (1965). Calcareous Nannofossils. In Kummel, B. and Raup, D. (eds.), Handbook of Paleontological Techniques,. In Freeman W.H., San Francisco, pp. 3-7.

HAY, W. W. (1977). Calcareous Nannofossils. In Ramsay, A. T.S. (ed.). Oceanic Micropal., 2, pp.1055-1200. Academic Press, London.

HAY, W.W. and TOWE, K. M. (1963). Microrhabdulus belgicus, a new species of nannofossil. Micropaleontology, **9**, pp.95-96.

HAY, W.W. MOHLER, H. and WADE, M.C. (1966). Calcareous nannofossils from Nal'Chik (North-West Caucasus). Eclogae Geol. Helv., **59**, pp. 379-399.

HAY, W. and MOHLER, H. (1967). Calcareous nannoplankton from Early Tertiary rocks at Pont Labau (France) and Paleocene-Early Eocene correlations. J. Paleont., **41**, no. 6, pp. 1505-1541.

HAY, W.W., MOHLER, H.P., ROTH, P.H., SCHMIDT, R.R. and BOUDREAUX, J.E., (1967). - Calcareous nannoplankton zonation of the Cenozoic of the Gulf Coast and Caribbean-Antillean area and transoceanic correlation. Trans. Gulf. Coast Assoc. Geol. Soc., **17**, pp. 428-480.

HERMINA, M.H. (1968). Geology of the North-Western Approaches of Kharga. General Egyptian Organisation for Geological Research and Mining, Geological Survey, **44**, pp.1-88.

HIBBERD D.J. (1976). The ultrastructure and taxonomy of the Chrysophyceae and Prymnesiophyceae (Haptophyceae): a survey with some new observations on ultrastructure of the Chrysophyceae. Bot. J. Linn. Soc., **72**, pp. 55-80.

HIBBERD D.J. (1980). PRYMNESIOPHYTES (=HAPTOPHYTES). Development in Marine Biology, 2, pp. 273-317

HOEK, J. (1978). Algen: Einfuhrung in die Phycologie. Thieme Verlag, Stuttgart.

HOFFMANN, N. (1970a). Coccolithineen aus der weissen Schreibkreide (Unter Maastricht) von Jasmund auf Rugen. Geologie, **19**, pp. 846-879.

HOFFMANN, N. (1970b). Placozygus n. gen. (Coccolithineen) aus der Oberkreide des Nordlichen Mitteleuropas. Geologie, **19**, pp. 1004-100w.

HUXLEY, T.H., (1858). Report in Deep Sea Soundings in North Atlantic Ocean between Ireland and Newfoundland made by H.M.S. Cyclops, (Camdr. J. Dayman), Admirality, London, p.64.

KAMPTNER, E. (1927). Beitrag zur Kenntnis adriatischer Coccolithophoriden. Arch. Protistenk., **58**, pp. 173-184.

KAMPTNER, E. (1948). Coccolithen aus dem Torton des Inneralpinen Wiener Beckens. Sitzungsber. Osterr. Akad. Wiss., Math.-Naturiw. Kl., Abt I, **157**, pp.1-16.

KAMPTNER, E. (1955). Fossile Coccolithineen-Sketettreste aus Insulinde. Eine mikropalaonologische Untersuchung. K. Neder. Akad. Wet., Afd. Natuurk. Ser. 2, **50**, pp.1-105.

KAMPTNER, E. (1963). Coccolithineen-Skelettreste aus Tiefseeablagerungen des Pazifischen Ozeans. Naturhist. Mus. Wien. Ann., **66**, pp.139-204.

KERDANY, M. T. (1970). Lower Tertiary nannoplanktonic zones in Egypt. Newsl. Stratigr., 1, no. 2, pp. 35-48.

KRASHENINNIKOV, V.A., and ABDEL-RAZIK, T.M. (1969). Zonal stratigraphy of Paleocene in Quseir (Red Sea Coast). Proc. Third African Micropal. Coll. The National Inforamtion and Documentation Centre, Ciaro, pp. 299-309.

LEMMERMANN, E. (1908). Flagellatae, Chlorophyceae, Coccosphaerales und Silicoflagellatae. In Bandtik and Apstein, C. (eds.), Nordisches Plankton. Botanischer, **40**, pp.1-35.

LOEBLICH, A.R. and TAPPAN, H. (1963). Type fixation and validation of certain calcareous nannoplankton genera. Proc. Biol. Soc. Wash., **76**, pp. 191-196.

LOEBLICH, A.R. and TAPPAN, H. (1971). Annotated index and bibliography of the calcareous nannoplankton VI. Phycologia, **10**, pp.315-339.

LOEBLICH, A.R. and TAPPAN, H. (1973). Annotated index and bibliography of the calcareous nannoplankton VII. Jour. Paleont., **47**, pp. 715-759.

LOHMANN, H. (1902). Die Coccolithophoridae, eine Monographie der Coccolithen bildenden Flagellaten, zugleich ein Beitrag zur Kenntnis des Mittelmeeraufriebs. Arch. Protistenk., **1**, pp. 89-165.

LOHMANN, H. (1920). Die Revolkerung des Ozeans mit Plankton nach den Ergebnissen der Zentrifugenfange wahrend der "Deutschland" 1911. Arch. Biont., **4** (3), pp.1-617.

MANIVIT, H. (1971). Les Nannofossiles calcaires du Crétacé francais (Aptien-Maestrichtien). Essai de biozonation appuyée sur les stratotypes. Thèse, Universite de Paris, pp. 1-187.

MANIVIT, H., PERCH-NIELSEN, K., PRINS, B. and VERBEEK, J, W. (1977). Mid-Cretaceous calcareous nannofossil biostratigraphy. Proc. Kon. Neder. Akad. Wetensch., Series B, **80**, pp. 169-181.

MARTINI, E. (1958). Discoasteriden und verwandte Formen im NW-Deutschen Eozan (Coccolithophoridae). Taxonomische untersuchungen. Senckenb. Lethaea, **39**, pp. 353-388.

MARTINI, E. (1961). Nannoplankton aus dem Tertiar und der obersten Kreide von SW-Frankreich. Senckenb. Lethaea, **42**, pp. 1-41.

MARTINI, E. (1970). Standard Palaeogene calcareous nannoplankton zonation. Nature, 226, pp. 560-561.

MARTINI, E. (1971). Standard Tertiary and Quaternary calcareous nannoplankton zonation. In Farinacci, A.(ed.), Proceed. Second Planktonic Conf., Roma 1970, 2, pp.739-785.

MARTINI, E. (1976). Cretaceous to Recent calcareous nannoplankton from the Central Pacific Ocean, Deep Sea Drilling Project, Leg 33. In Schlanger S.O., Jackson E.D., et al., Initial Report of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), 33, pp. 383-423.

MAZHAR, A., ENANY, N. and ABDEL KADER, Y. (1979). Contributions to the Cretaceous-Early Tertiary stratigraphy of El Galala El Qubliya Plateau. Annals of the Geological Survey of Egypt, vol. IX, pp.377-386.

MONECHI, S. (1985). Campanian to Pleistocene calcareous nannofossil stratigraphy from the Northwest Pacific Ocean, Deep Sea Drilling Project Leg 86, Init. Repts. Deep Sea Drilling Project 86. Washington (U.S. Govt. Printing Office), 86, pp. 301-336.

MÜLLER, C. (1974). Calcareous nannoplankton Leg 25 (Western Indian Ocean). In Simpson E.S.W., Schlich, R. et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), 25, 579-633.

MÜLLER, C. (1976). Tertiary and Quaternary calcareous nannoplankton in the Norwegian-Greenland Sea., Deep Sea Drilling Project, Leg 38. In Talwani M., Udintesev, G., et al., Initial Reports of Deep Sea Drilling Project. Washington, (U.S. Government Printing Office), 38, pp. 823-841.

MURRAY, G. and BLACKMAN, V.H. (1898). On the nature of the coccospheres and rhabdospheres. Phil. Trans. Roy. Soc., London, Series B,190, pp.427-441.

NOËL, D. (1956). Coccolithes des terrains Jurassiques de l'Algérie: Publications du Service de la Carte Géologique de l'Algérie, Series 2, 8, pp.303-345.

NOËL, D. (1958). Etude des Coccolithes du Jurassique et du Crétacé inférieur. Publications du Service de la Carte Geologique de l'Algerie, Series 2, 20, pp.155-196.

NOËL, D. (1965a). Note preliminaire sur des coccoliths jurassiques. Cahiers de Micropaleontologie, 1, pp. 1-12.

NOËL, D. (1965). Sur les coccolithes du Jurassique Europeen et d'Afrique du Nord. Essai de classification des coccolithes fossiles. Edition du Centre National de la Recherche Scientifique, Paris, pp.1-209.

NOËL, D. (1970). Coccolithes Crétacés de la craie Campanienne du Bassin de Paris. Edition du Centre National de la Recherche Scientifique, Paris, pp. 1-129.

OKADA, H. and THIERSTEIN, H. R. (1979). Calcareous Nannoplankton, Leg. 43, Deep Sea Drilling Project. In Tucholke, B. E., Vogt, P.R. et al., Initial Report of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), 43, pp. 507-573.

PERCH-NIELSEN, K. (1968). Der Feinbau und die Klassifikation der Coccolithen aus dem Maastrichtien von Danemark. Kong. Danske Videnskab. Selskab., Biol. Skr., 16, pp. 1-96.

PERCH-NIELSEN, K. (1969a). Elektronenmikroskopische Untersuchungen der Coccolithophoriden der Dan Scholle von Katharinenhof (Fehmarn). N. Jb. Geol. Pal. Abh., 132, pp.317-332.

PERCH-NIELSEN, K. (1969b). Die Coccolithen einiger dinischer Maastrichtien und Danien lokalitäten. Bull. Geol. Soc. Denmark, 19, pp. 51-66.

PERCH-NIELSEN, K. (1971a). Durchsicht Tertiärer Coccolithen. In Farinacci, A.(ed.), Proceed. Second Plankt. Conf., Roma 1970, **2**, pp. 939-980.

PERCH-NIELSEN, K. (1971b). Neue Coccolithen aus dem Paleozän von Dänemark der Bucht von Biskaya und der Eozän der Labrador sea. Bull. Geol. Soc. Denmark, **21**, p. 51-66.

PERCH-NIELSEN, K. (1971c). Einige neue Coccolithen aus dem Paleozan der Bucht von Biskaya. Bull. Geol. Soc. Denmark, **20**, pp. 347-361.

PERCH-NIELSEN, K. (1971d). Elektronmikroskopische Untersuchungen an Coccolithen und verwandte Formen aus dem Eozän von Danemark. Kong. Danske Vidensk. Selsk. Biol. Skr., **18**, pp.1-76.

PERCH-NIELSEN, K. (1972). Remarks on Late Cretaceous to Pleistocene Coccoliths from the North Atlantic. In Laughton A.S., Berggren, W.A., et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), **12**, pp. 1003-1069.

PERCH-NIELSEN, K. (1973). Neue Coccolithen aus dem Maastrichtien von Danemark, Madagaskar und Aegypten. Bull. Geol. Soc. Denmark,. **22**, pp. 306-333.

PERCH-NIELSEN, K. (1977). Albian to Pleistocene calcareous nannofossils from the Western South Atlantic, Deep Sea Drilling Project, Leg 39. In Supko, P.R., Perch-Nielsen, K., et al., Initial Reports of the Deep Sea Drilling Project, **39**, pp. 699-823.

PERCH-NIELSEN, K. (1979a). Calcareous nannofossils from the Cretaceous between the North Sea and the Mediterranean. In Aspekta der kreide Europas. IUGS, Series A., **6**, Stuttgart, pp. 223-272.

PERCH-NIELSEN, K. (1979b). Calcareous nannofossil zonation at the Cretaceous/Tertiary Boundary in Denmark. In: Birkelund T. and Bromley, R. G. (eds.), Cretaceous-Tertiary Boundary Events, 1. University of Copenhagen, pp.115-135.

PERCH-NIELSEN, K. (1981a). New Maastrichtian and Paleocene calcareous nannofossils from Africa, Denmark, the USA and the Atlantic and some Paleocene lineages. Eclogae Geol. Helv., 73, no. 3, pp. 831-863.

PERCH-NIELSEN, K. (1981b). Les Coccolithes du Paléocène près de El Kef Tunisia et leurs ancètres. Cah. Micropaléontol., 3, pp.7-23.

PERCH-NIELSEN, K. (1984). Validation of new combinations. In INA Newsletter, 6 (1), pp.42-46.

PERCH-NIELSEN, K. (1985). Mesozoic and Cenozoic calcareous nannofossils. In Bolli, H.M., Saunders, J.B., et al. (eds.), Plankton stratigraphy. Cambridge University Press, Cambridge, pp.329-554.

PERCH-NIELSEN, K. (1986). New Mesozoic and Paleogene calcareous nannofossils. Eclogae geol. Helv., 79, no.3, pp.835-847.

PERCH-NIELSEN, K., SADEK, A., BARAKAT, M., G. and TELEB, F. (1978). Late Cretaceous and Early Tertiary calcareous nannofossils and planktonic foraminifera zones from Egypt. Ann. Min. Geol., Tunis, 28, Actes du VIe Colloque African de Micropaleotologie, Tunis 1974, Tome II, pp. 337-403.

PERCH-NIELSEN, K., MCKENZIE, J. and QIZIANG, H. (1982). Biostratigraphy and isotope stratigraphy and the "Catastrophic" extinction of calcareous nannoplankton at the Cretaceous/Tertiary boundary. In silver L.T. et al. (eds.), Geological Implications of Impacts of Large Astroids and Comets on the Earth, Special Paper 190, Geological Society of America, pp. 353-371.

PIENAAR, R. N. (1968). Upper Cretaceous coccolithophorides from Zululand, South Africa. Paleontology, 11, pp.361-367.

PRINS, B. (1971). Speculations on relations, evolution and stratigraphic distribution of Discoasters. In Farinacci, A.(ed.), Proc. Second Plankt. Conf., Roma 1970, 2, pp. 1017-1038.

PROTO DECIMA, F., ROTH, P.H. & TODESCO, L. 1975. Nannoplacton calcareou del Paleocene e dell' Eocene della Sezione di Possagno. Schweiz, Palaontol. Abh., 97, pp.35-55.

PROTO-DECIMA, F., MEDIZZ, F. and TODESCO. L. (1978). Southeastern Atlantic Leg. 40 calcareous nannofossils. In Bolli H.M., Ryan , W.B.F., et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Pringing Office), 40, pp. 571-634.

REINHARDT, P. (1964). Einige Kalkflagellaten-Gattungen (Coccolithophoriden, Coccolithineen) aus dem Mesozoikum Deutschlands. Monatsber. Deutsch. Akad. Wiss. Berlin, 6, pp. 749-759.

REINHARDT, P. (1965). Neue Familien fur fossile Kalkflagellaten (Coccolithophoriden, Coccolithineen). Monatsber. Deutsch. Akad. Wiss. Berlin, 7, pp. 30-40.

REINHARDT, P. (1966a). Zur Taxionomie und Biostratigraphie des fossilen Nannoplanktons aus dem Malm, der Kreide und dem Attertiar Mitteleuropas. Freiberger Forschungshefte, Palaontologie, Series C, 196, pp. 5-109.

REINHARDT, P. (1966b). Fossile Vertreter coronoider und styloider Coccolithen (Familie Coccolithaceae Poche 1913). Monatsber. Deutsch. Akad. Wiss. Berlin, 8, pp. 513-524.

REINHARDT, P. (1967). Fossile Coccolithen mit rhagoidem Zentralfeld (Fam. Ahmuellerellaceae, subord. Coccolithineae). Neues Jahrb. Geol. Pal., Monatshefte 1967, pp. 163-178.

REINHARDT, P. (1970a). Synopsis der Gattungen und Arten der Mesozoischen Coccolithen und anderer Kalkiger Nannofossilien, Teil I. Freiberger Forschungshefte, Palaontologie, Series C, **260**, pp. 5-32.

REINHARDT, P. (1970b). Synopsis der Gattungen und Arten der Mesozoischen Coccolithen und anderer Kalkiger Nannofossilien, Teil II. Freiberger Forschungshefte, Paläontologie, Series C, **265**, pp. 41-111.

REINHARDT, P. (1971). Synopsis der Gattungen und Arten der Mesozoischen Coccolithen und anderer Kalkiger Nannofossilien, Teil III. Freiberger Forschungshefte, Paläontologie, Series C, **267**, pp. 19-41.

REINHARDT, PETER, and GORKA, H. (1967). Revision of some Upper Cretaceous coccoliths from Poland and Germany. N. Jb. Geol. Palaol. Abh., **129**, pp.240-256.

RISATTI, J.B. (1973). Nannoplankton Biostratigraphy of the Upper Bluffport Marl-Lower Prairie Bluff Chalk interval (Upper Cretaceous) in Mississippi. In Smith, L.A. and Hardenbol. J. (eds.)., Proc. Symp. Calcareous Nannofossils, Gulf Coat Geol. Soc., pp.3-57.

ROMEIN, A.J.T. (1977). Calcareous nannofossils from Cretaceous/Tertiary boundary interval in the Barranco del Gredero (Caravaca, Prov. Murcia, S.E. Spain). Proc. Kon. Ned. Akad. Wetensch., Ser. B., **80**, (4), pp. 256-279.

ROMEIN, A.J.T. (1979). Lineages in Early Paleogene calcareous nannoplankton. Utrecht Micropal. Bull., **22**, pp. 1-231.

ROMEIN, A.J.T. (1980). <u>Discoaster drieveri</u>, nomen novum pro <u>Discoaster bramlettei</u> (Bukry & Pencival 1971) Romein (1979) non Martini (1958). In INA Newsletter, **2** (1), pp.35.

ROOD, A.P., HAY, W.W. and BARNARD, T. (1971). Electron microscope studies of Oxford Clay coccoliths. Eclogae Geol. Helv., **64**, pp. 245-272.

ROOD, A.P., HAY, W.W. and BARNARD, T. (1973). Electron microscope studies of Lower and Middle Jurassic Coccoliths. Eclogae Geol. Helv., **66**, pp.365-382.

ROTH, P. H. (1973). Calcareous nannofossils, Leg 17. Deep Sea Drilling Project. In Winterer, L.E., Ewing, J. I. et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), **17**, pp. 695-795.

ROTH, P. H. (1978). Calcareous Nannoplankton Biostratigraphy and Oceanography of the Northwestern Atlantic Ocean. In Benson, W.E., Sheridan, R.E., et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), **44**, pp. 731-759.

ROTH, P. H. and THIERSTEIN, H. R. (1972). Calcareous nannoplankton, Leg 14, Deep Sea Drilling Project. In Hayes D.E., Pimm, A.C. et al., Initial Reports of the Deep Sea Drilling Project. Washington, (U.S. Government Printing Office), **14**, pp. 421-485.

ROTH, P.H. and BOWDLER J.L. (1979). Evolution of the calcareous nannofosil genus Micula in the Late Cretaceous. Micropaleontology, **25**, no.3, pp.272-280.

SAID, R. (1962). The Geology of Egypt. Elsevier Publ. Co., pp.1-377.

SCHILLER, J. (1926). Über Fortpflanzung, geissellose, Gattungen und die Nomenklatur der Coccolithophoraceen nebst Mitteilung über Copulation bei Dinobryon. Arch. Protistenk. 53, pp.326-342.

SCHILLER, J. (1930). Coccolithineae. In L. Rabenhorst's Kryptogamen -Flora, **10**. Akademische Verlagsgesellschaft, Leipzig, pp.89-267.

SCHWARZ, E.H.L. (1894). Coccolithus. Ann. Mag. Nat. Hist., **6(14)**, pp.341-346.

SEYVE, C. (1984). The Cretaceous-Tertiary Boundary at Pont Labau (Pyrienees-Atlantiques, France). Bull. Centres Rech. Explor. Prod. Elf-Aquitaine, **8**, 2, pp. 385-423.

SHAMRAI, I.A. (1963). Certain forms of Upper Cretaceous and Paleogene coccoliths and Discoaster from the Southern Russian platform. Izv. Vyssh. Ucheb. Zaved. Geol. i Razv., **6**, (4), pp. 27-40.

SHAFIK, S. and STRADNER, H. (1971). Nannofossils from the Eastern Desert, Egypt, with reference to Maastrichtian Nannofossils from the USSR. Jb. Geol. Bundesanst., Wien, **17**, pp.69-104.

SIESSER, W. G., WARD, D. J. AND LORD, A. L., (1987). Calcareous nannoplankton biozonation of the Thanetian Stage (Palaeocene) in the type area. J. Micropalaeontol., **6**, (1), pp. 85-102

SISSINGH, W. (1977). Biostratigraphy of Cretaceous calcareous nannoplankton. Geol. Mijnb., **56**, pp. 37-65.

SMIT, J. (1977). Discovery of a planktonic foraminiferal association between the A. mayaroensis Zone and the G. eugubina Zone at the Cretaceous/Tertiary boundary in the Barranco del Gredero (Caravaca, S.E. Spain), a preliminary report. Proc. Kon. Ned. Akad. Wetensch., Series B, **80**, pp. 280-301.

SMITH, C.C. (1981). Calcareous nannoplankton and stratigraphy of the Late Turonian, Coniacian and Early Santonian age of the Eagle Ford and Austin Groups of Texas. Geol. Surv. Prof. paper **1075**, pp. 1-98.

STEINMETZ, J.C. and STRADNER, H. (1984). Cenozoic calcareous nannofossils from Deep Sea Drilling Project Leg 75. In Hay W.W, et al., Initial Reports of the deep Sea Drilling Project. Washington (U.S. Government. Printing Office), **75**, pp. 671-753.

STOVER, E. (1966). Cretaceous coccoliths and associated nannofossils from France and the Netherlands. Micropal., 12, no. 2, pp. 133-167.

STRADNER, H. (1958). Die fossilen Discoasteriden Österreichs. I Teil, Erdoel-Z., 74, 6, pp. 178-188.

STRADNER, H.(1959a). Die fossilen Discoasteriden Österreichs, II Teil, Erdoel-Z., 75, pp.472-488.

STRADNER, H.(1959b). First report on the discoasters of the Tertiary of Austria and their stratigraphic use. Fifth World Petr. Congr., 1, paper 60, pp.1081-1095.

STRADNER, H. (1961). Vorkommen von Nannofossilien im Mesozoikum und Alttertiar. Erdoel-Z., 77, pp. 77-88.

STRADNER, H. (1962). Über neue und wenig bekannte Nannofossilien aus Kreide und Alttertiar. Verh. Geol. Bundesanst., Wien, 2, pp. 363-377.

STRADNER, H. (1963). New contributions to Mesozoic stratigraphy by means of nannofossils. Proceedings of the Sixth World Petroleum Congress, Section 1, Paper 4 (preprint), pp. 1-16

STRADNER, H. in GOHRBANDT, K. (1963). Zur Gliederung des Päläeogen im Helvetikum nördlich Salzburg nach planktonischen Foraminiferen. Mitt. Geol. Ges., Wien, 56, pp.72-81.

STRADNER, H. and PAPP, A. (1961). Tertiäre Discoasteriden aus Osterreich und deren stratigraphische Bedeutung, mit Aimweisem auf Mexiko, Rumänien und Italian. Jb. Geol. Bundesanst., Wien, 7, pp. 1-160.

STRADNER, H. and ADAMIKER, D. (1966). Nannofossilien aus Bohrkernen und ihre elektronenmikroskopische Bearbeitung. Erdöl-Erdgas-Zeitschr., 82, pp. 330-341.

STRADNER, H., ADAMIKER, D. and MARESCH, O. (1968). Electron Microscope Studies on Albian Calcareous Nannoplankton from the Delft 2 and Leidschendam 1 deep wells, Holland. Verh. Kon. Ned. Akad. Wet., Afd. Nat., **24**, pp.1-107.

STRADNER, H. and STEINMETZ. J. (1984). Cretaceous calcareous nannofossils from the Angola Basin, Deep Sea Drilling Project Leg75. In HAY, W.W. et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), **75**, pp. 565-649.

SUJKOWSKI, Z., (1931). Petrograffja Kredy Polski. Kreda z glebokiego wiercenia w Lublinie w porownaniu z kreda niektorych innych obszarow Polski: Spraw. Polsk. Inst. Geol, **6**, pp.485-628.

SULLIVAN, F. R. (1964). Lower Tertiary nannoplankton from the California Coast Ranges. I. Paleocene. Univ. Calif. Publ. Geol. Sc., **44**, pp. 163-227.

SULLIVAN, F.R. (1965). Lower Tertiary nannoplankton from the California Coast ranges. 11. Eocene. Univ. Calif. Publ. Geol. Sc., **53**, pp.1 1-52.

TAN SIN HOK (1927). Discoasteridae incertae sedis. Proc Sect. Sci. Kon. Akad. Wet. Amsterdam. **30**, 411-419.

TAYLOR, R. J. and HAMILTON, G. B. (1982). Techniques. In Lord A.R. (ed.), A stratigraphical Index of Calcareous Nannofossils. Ellis Horewood, Chichester, pp. 11-15.

THEODORIDIS, S.A. (1984). Calcareous nannofossils biozonation of the Miocene and revision of the Helicolithus and Discoaster. Utrecht Micropal. Bull., **32**, pp.1-271.

THIERSTEIN, H. (1974). Calcareous Nannoplankton, Leg. 26 Deep Sea Drilling Project. In Davies, T.A., et al., Initial reports of the Deep Sea Drilling Project. Washington (U.S. Government printing Office), **26**, pp. 619-667.

THIERSTEIN, H. (1976). Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. Marine Micropal., 1, no.4, pp. 325-362.

THIERSTEIN, H. (1980). Selective Dissolution of Late Cretaceous and Earliest Tertiary Calcareous Nannofossils: Experimental Evidence. Cretaceous Research, 2, pp. 165-176.

THIERSTEIN, H. (1982). Terminal Cretaceous plankton extinction: A critical assessment. In Silver L.T. et al. (eds.), Geological Implications of Impacts of Large Asteroids and Comets on the Earth, special Paper **190**. Geological Society of America, pp. 385-399.

THIERSTIEN, H. and OKADA, H. (1979). The Cretaceous-Tertiary boundry event in the North Atlantic. In Tucholke, B.E. et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), **43**, pp. 601-616.

VAROL, O. (1983). Late Cretaceous-Paleocene Calcareous Nannofossils from the Kokaksu Section (Zonguldak, Northern Turkey). N.Jb. Geol. Palaont. Abh., **166**, 3, pp.431-460.

VEKSHINA, V. N. (1959). Coccolithophoridae of the Maastrichtian deposits of the West Siberian Lowland. Trudy Sibir. Nauch-Issled. Inst. Geol. Geofiz. Min. Syrya, **2**, pp. 56-81.

VERBEEK, J. W. (1976). Upper Cretaceous calcareous nannoplankton zonation in a composite section near El-Kef, Tunisia. I. and II. Proc. Kon. Ned. Akad. Wet., Ser.B., **79**, pp. 129-148.

VERBEEK, J. W. (1977). Calcareous nannoplankton biostratigraphy of Middle and Upper Cretaceous deposits in Tunisia, Southern Spain and France. Utrecht Micropal. Bull., **16**, pp.1-157.

WALLICH, G. C. (1861). Remarks on some novel phases of organic life, and on the boring powers of minute annelids, at great depths in the sea. Ann. Mag. Nat. Hist., Ser. 3, **8**, pp.52-58.

WALLICH, G.C. (1877). Observations on the Coccosphere. Ann. Mag. Nat. Hist., Ser. 4, **19**, pp. 342-350.

WISE, S.W. and WIND, F. H. (1976). Mesozoic and Cenozoic calcareous nannofossils recovered by Deep Sea Drilling Project Leg 36, drilling on the Falkland Plateau, southwest Atlantic sector of the Southern Ocean. In Barker, P.F., Dalziel, I.W.D., et al., Initial Reports of the Deep Sea Drilling Project. Washington (U.S. Government Printing Office), **36**, pp.269-492.

WIND, F.H. (1974). Calcareous nannoplankton of the Salt Mountain Limestone (Jackson, Alabama). Trans. Gulf Coast Assoc. Geol. Soc., **24**, pp. 327-334.

WIND, F.H. and WISE, S.W. (1978). Mesozoic holoccoliths, Geology, **6**, pp. 140-142.

WORSLEY, T. R. (1974). The Cretaceous-Tertiary boundary event in the ocean. In Hay, W. (ed.), Studies in Paleo-oceannolography. Soc. Econ. Pal. Min. spec. publ., **20**, pp. 94-125.

WORSLEY, T. R. and MARTINI, E. (1970). Late Maastrichtian nannoplankton provinces. Nature, **225**, pp. 1242-1243.

YOUSSEF, M.I. (1957). Upper Cretaceous rocks in Kosseir area. Bull. Inst. Desert Egypt, **7**, (2), pp. 35-54.

ZITTLE, A.K. (1883). Beitrage zur Geologie und Palaeontologie der Libyschen wuste und der angrenzenden Geblete von Aegypten. Palaeontographica, **30**, pp. 1-142.

PLATE 1

Fig. 1 Arkhangelskiella cymbiformis Vekshina, UCL-1877-28, Gebel Tarbouli (32), Lithraphidites quadratus Zone, 4500x, distal view.

Fig. 2 Arkhangelskiella specillata Vekshina, UCL-1877-25 Gebel Tarbouli (32), Lithraphidites quadratus Zone, 3700x, distal view.

Fig. 3 Broinsonia parca (Stradner) Bukry, UCL-1865-4, Gebel Tarbouli (4), Quadrum trifidum Zone, 3300x, distal view.

Fig. 4 Gartnerage obliquum (Stradner) Reinhardt, UCL-1870-17, Gebel Tarbouli (20), Arkhangelskiella cymbiformis Zone, 5000x, proximal view.

Fig. 5 Kamptnerius magnificus Deflandre, UCL-1925-11, Wadi Mellaha (46), Lithraphidites quadratus Zone, 3800x, distal view.

Fig. 6 Kamptnerius tabulatus Perch-Nielsen, UCL-2133-6, Wadi Mellaha (68) Nephrolithus frequen Zone, 5000x, distal view.

Fig. 7 Bidiscus ignotus (Górka) Hoffman, UCL-1919-31, Wadi Tarfa (38), Lithraphidites quadratus Zone, 15000x, distal view.

Fig. 8 Ahmuellerella octoradiata (Górka) Reinhardt, UCL-1934-5, Wadi Mellaha (72), Nephrolithus frequens Zone, 5900x, distal view.

Fig. 9 Ahmuellerella regularis (Górka) Verbeek, UCL-2130-8, Wadi Mellaha (30) Lithraphidites quadratus Zone, 8250x, distal view slightly overgrown specimen.

Fig. 10 Ahmuellerella regularis (Górka) Verbeek, UCL-2152-2 Wadi Tarfa (52) Nephrolithus frequens Zone, highly overgrown specimen, 6000x, distal view.

Fig. 11 Ahmuellerella regularis (Górka) Verbeek, UCL-2152-1, 6000x, oblique proximal view of specimens Figure 10.

Fig. 12 Vekshinella ara Gartner, UCL-1919-10, Wadi Mellaha (30) Lithraphidites quadratus Zone, 9000x, oblique distal view.

Fig. 13 Vekshinella ara Gartner, UCL-1919-12, Wadi Mellaha (30), Lithraphidites quadratus Zone, 2600x, specimen with long spine, side view.

Fig. 14 Vekshinella compacta (Bukry) n. comb., UCL-2130-14, Wadi Mellaha (30), Lithraphidites quadratus Zone, 10000x, proximal view.

Fig. 15 Vekshinella compacta (Bukry) n. comb., UCL-1919-7, Wadi Mellaha (30), Lithraphidites quadratus Zone, 9750x, distal view.

PLATE 1

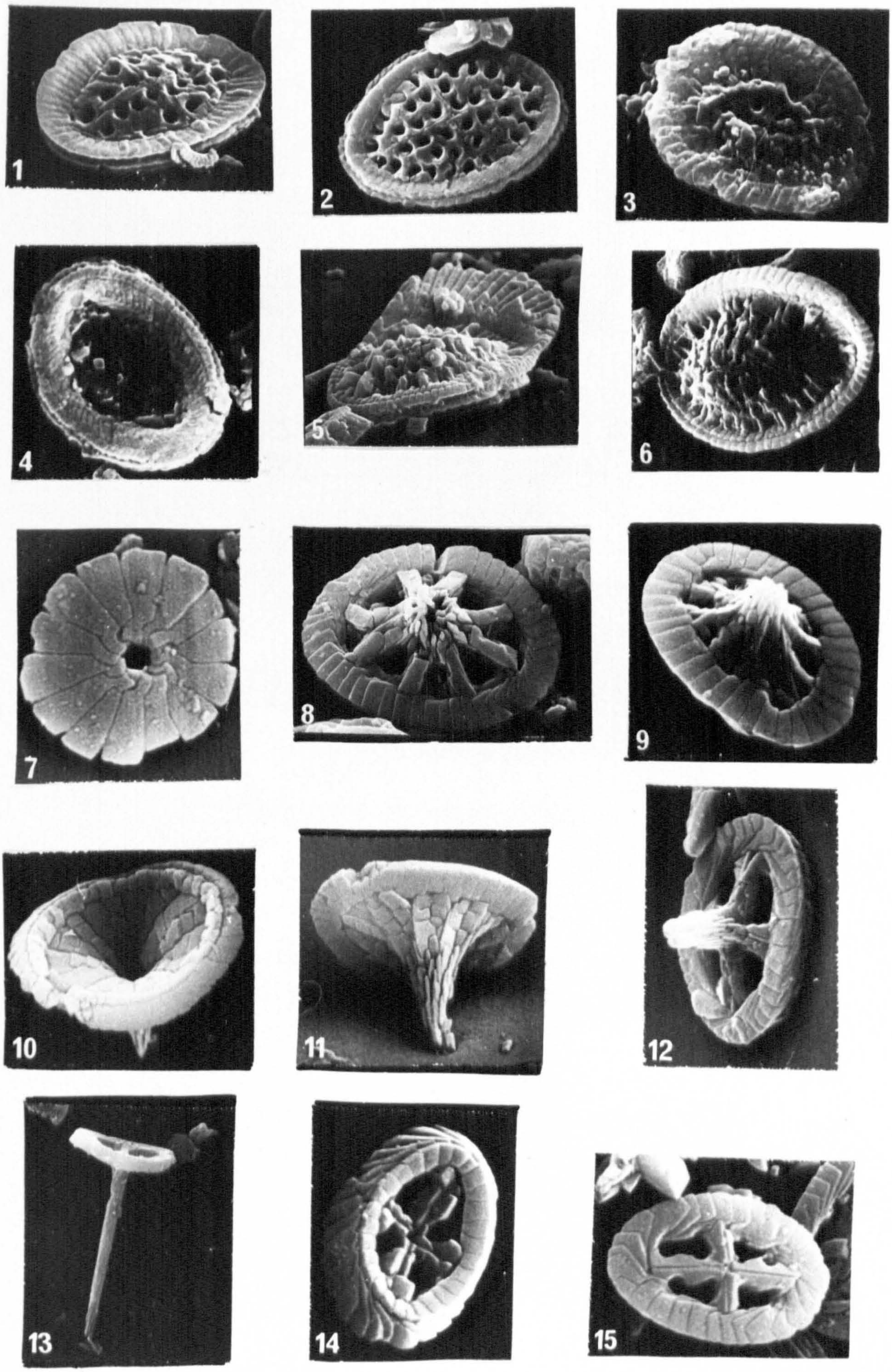


PLATE 2

Fig. 1 Vekshinella dorfii (Bukry) n. comb., UCL-2135-30, Wadi Mellaha (8), Arkhangelskiella cymbiformis Zone, 8300x, proximal view.

Fig. 2 Vekshinella elliptica Gartner, UCL-2131-1, Wadi Mellaha (30), Lithraphidites quadratus Zone, 9200x, distal view.

Fig. 3 Vekshinella crux (Deflandre and Fert) Risatti, UCL-2131-27, Wadi Mellaha (30), Lithraphidites quadratus Zone, 11000x, distal view.

Fig. 4 Vekshinella dibrachiata Gartner, UCL-2133-22, Wadi Mellaha (68), Nephrolithus frequens Zone, 7000x, distal view.

Fig. 5 Rhagodiscus angustus (Stover) Reinhardt, UCL-2141-34, Wadi Mellaha (68), Nephrolithus frequens Zone, 4500x, proximal view.

Fig. 6 Rhagodiscus splendens (Deflandre) Verbeek, UCL-1919-15, Wadi Mellaha (30) Lithraphidites quadratus Zone, 3380x, side view.

Fig. 7 Tranolithus minimus (Bukry) Perch-Nielsen, UCL-1872-18, Gebel Tarbouli (24), Arkhangelskiella cymbiformis Zone, 12750x, proximal view.

Fig. 8 Tranolithus tarboulensis (Shafik and Stradner) n. comb., UCL-1877-9, Gebel Tarbouli (32), Lithraphidites quadratus Zone, 9380x, distal view.

Fig. 9 Tranolithus tarboulensis (Shafik and Stradner) n comb., UCL-2139-22, Wadi Mellaha (52), Lithraphidites quadratus Zone, 9000x, distal view.

Fig. 10 Glaukolithus diplogrammus (Deflandre) Reinhardt, UCL-2130-28, Wadi Mellaha (30), Lithraphidites quadratus Zone, 11500x, proximal view.

Fig. 11 Glaukolithus compactus (Bukry) Perch-Nielsen, UCL-1870-4, Gebel Tarbouli (16), Arkhangelskiella cymbiformis Zone, 6750x, proximal view.

Fig. 12 Glaukolithus compactus (Bukry) Perch-Nielsen, UCL-1870-2, Gebel Tarbouli (16), Arkhangelskiella cymbiformis Zone, 6400x, distal view.

Fig. 13 Placozygus sigmoides (Bramlette and Sullivan) Romein, UCL-1892-8, Gebel Tarbouli (56), Tribrachiatus contortus Zone, 3500x, oblique distal view.

Fig. 14 Placozygus sigmoides (Bramlette and Sullivan) Romein, UCL-1892-5 Gebel Tarbouli (56), Tribrachiatus contortus Zone, 4100x, distal view.

Fig. 15 Placozygus fibuliformis (Reinhardt) Hoffmann, UCL-1870-3 Gebel Tarbouli (16), Arkhangelskiella cymbiformis Zone, 7800x, proximal view.

PLATE 2

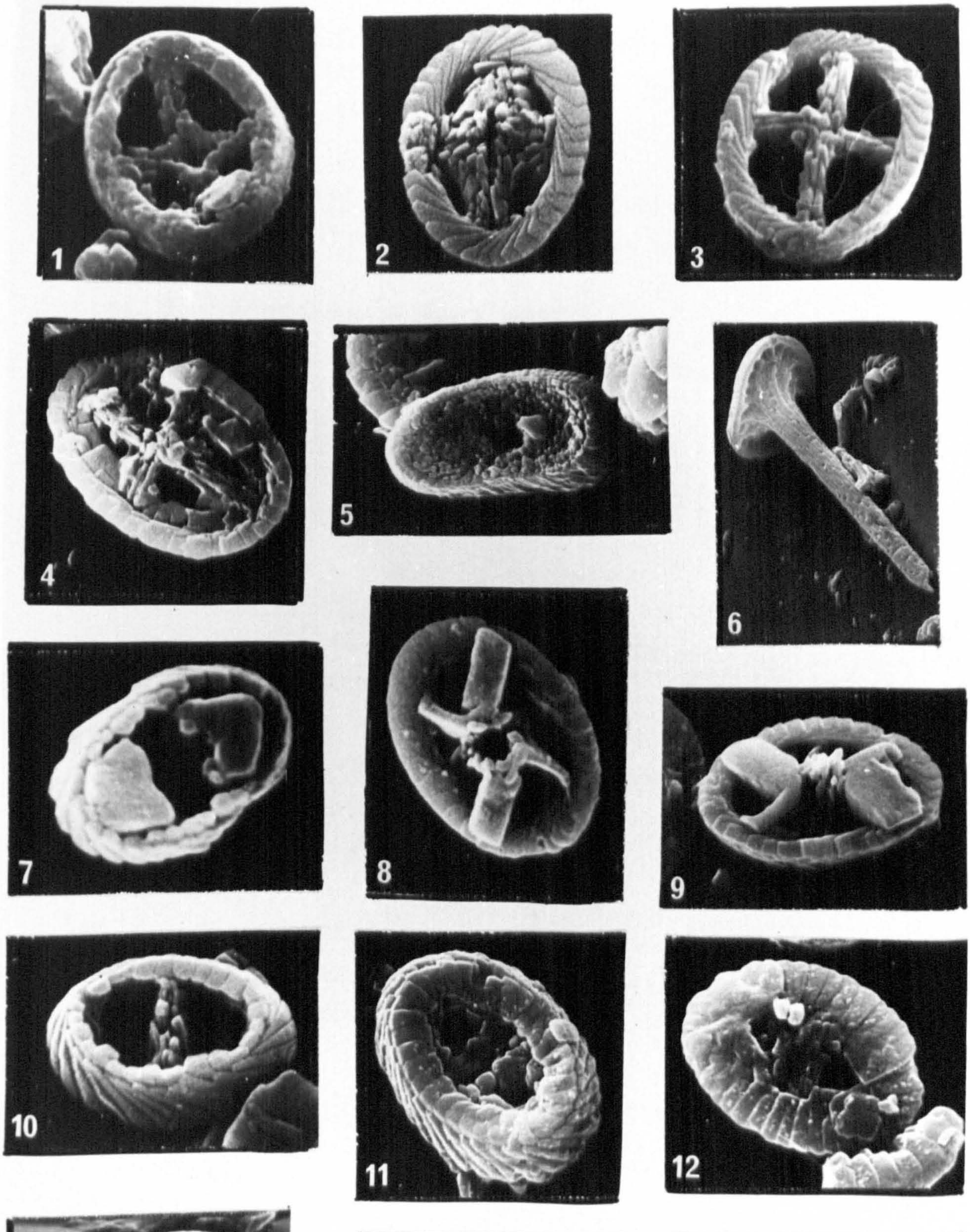


PLATE 3

Fig. 1 Placozygus fibuliformis (Reinhardt) Hoffman, UCL-1870-8, Gebel Tarbouli (16), Arkhangelskiella cymbiformis Zone, 7400x, distal view.

Fig. 2 Reinhardtites levis Prins and Sissingh, UCL-2136-31, Gebel Tarbouli (4), Quadrum trifidum Zone, 4330x, distal view.

Fig. 3 Reinhardtites levis Prins and Sissingh, UCL-2136-6, Gebel Tarbouli (4), Quadrum trifidum Zone, 4500x, proximal view.

Fig. 4 Diadochiastozygus saepes (Perch-Nielsen) n.comb., UCL-2067-34, Gebel Duwi (58), Ellipsolithus macellus Zone, 7800x, distal view.

Fig. 5 Diadochiastozygus imbriei (Haq and Lohmann) n. comb., UCL-2067-32, Gebel Duwi (58), Ellipsolithus macellus Zone, 10000x, proximal view.

Fig. 6 Diadochiastozygus imbriei (Haq and Lohmann) n. comb., UCL-2067-31, Gebel Duwi (58), Ellipsolithus macellus Zone, 10000x, proximal view.

Fig. 7 Diadochiastozygus eosaepes (Haq and Lohmann) n. comb., UCL-2067-22, Gebel Duwi (58), Ellipsolithus macellus Zone, 10000x, proximal view.

Fig. 8 Neochiastozygus perfectus Perch-Nielsen, UCL-2068-23, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 7100x, distal view.

Fig. 9 Neochiastozygus perfectus Perch-Nielsen, UCL-2062-24, Gebel Atshan (20), Discoaster multiradiatus Zone, 8000x, proximal view.

Fig. 10 Neochiastozygus junctus (Bramlette and Sullivan) Perch-Nielsen, UCL-2076-10, Gebel Atshan (24), D. multiradiatus Zone, 5200x, oblique proximal view.

Fig. 11 Intermediate form between Neochiastozygus perfectus and Neochiastozygus junctus UCL-2073-26, Gebel Atshan (24), Discoaster multiradiatus Zone, distal view.

Fig. 12 Neochiastozygus modestus Perch-Nielsen, UCL-2037-16, Wadi Tarfa (61), Fasciculithus tympaniformis Zone, 7700x, distal view.

Fig. 13 Neochiastozygus concinnus Perch-Nielsen, UCL-1972-24, Gebel Atshan (26), Discoaster multiradiatus Zone, 7500x, distal view.

Fig. 14 Neochiastozygus distintus (Bramlette and Sullvian) Perch-Nielsen, UCL-2051-21, Gebel Um El Ghanayem (40), Discoaster multiradiatus Zone, 6900x, distal view.

Fig. 15 Neochiastozygus protenus (Bramlette and Sullivan) Hay and Mohler, UCL-1995-19, Wadi Mellaha (86), Tribrachiatus contortus Zone, 7800x, distal view.

PLATE 3

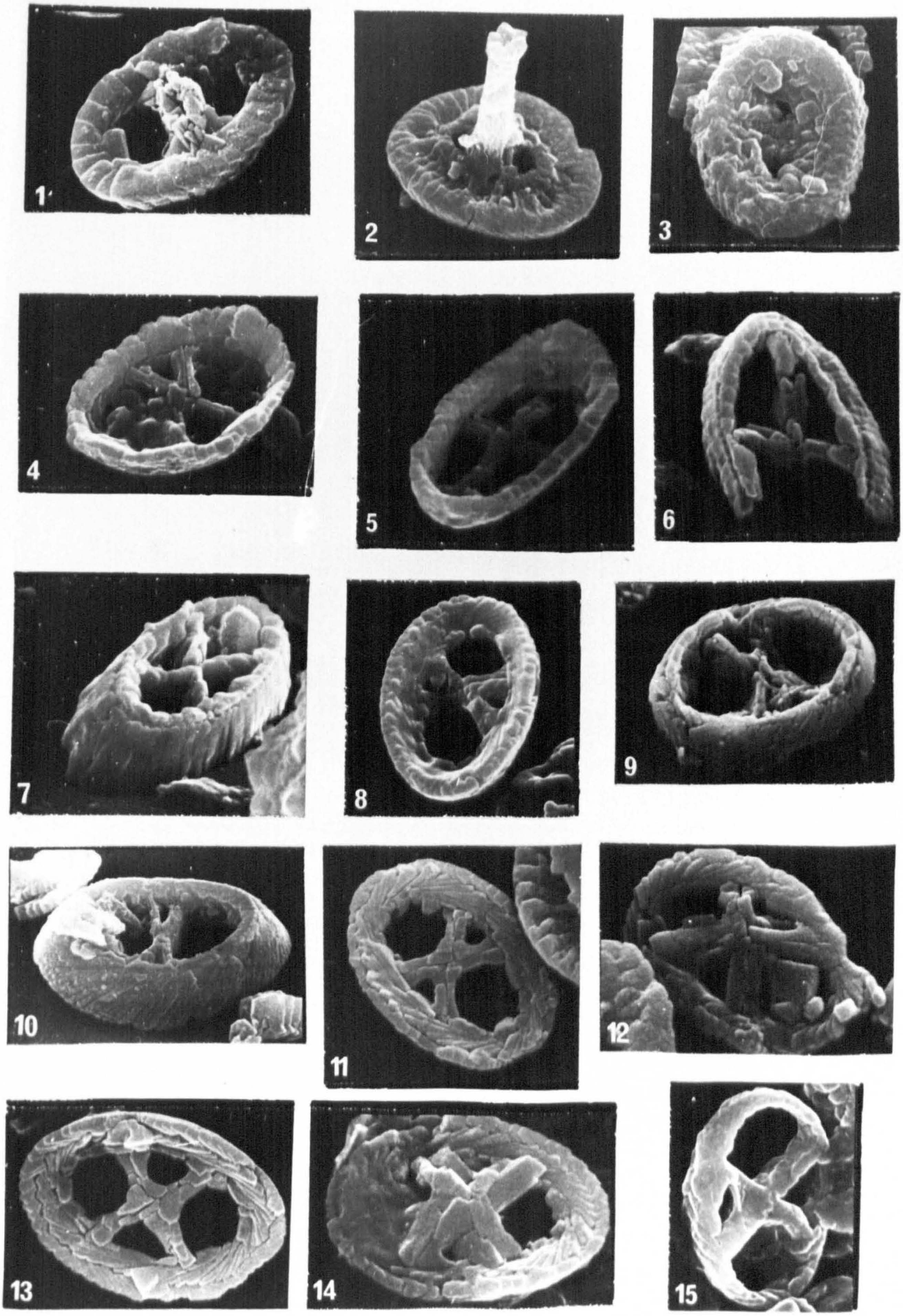


PLATE 4

Fig. 1 Lophodolithus nascens Bramlette and Sullivan, UCL-2084-17, Gebel Tarbouli (60), Tribrachiatus contortus Zone, 4000x, proximal view.

Fig. 2 Microrhabdulus belgicus Hay and Towe, UCL-1919-33, Wadi Mellaha (38), Lithraphidites quadratus Zone, 3800x, side view.

Fig. 3 Microrhabdulus decoratus Deflandre, UCL-1934-8, Wadi Mellaha (72), Nephrolithus frequens Zone, 1950x, side view.

Fig. 4 Lithraphidites carnialensis Deflandre, UCL-1919-21, Wadi Mellaha (30), Lithraphidites quadratus Zone, 5500x, side view.

Fig. 5 Lithraphidites praequadratus Roth, UCL-1919-17, Wadi Mellaha (30), Lithraphidites quadratus Zone, 4100x, side view.

Fig. 6 Lithraphidites quadratus Bramlette and Martini, UCL-1925-36, Wadi Mellaha (60), Lithraphidites quadratus Zone, 5770x, side view.

Fig. 7 Lithraphidites grossopectinatus Bukry, UCL-2132-21, Wadi Mellaha (72), Nephrolithus frequens Zone, 7200x, side view.

Fig. 8 Lithraphidites grossopectinatus Bukry, UCL-2139-29, Wadi Mellaha (52), Lithraphidites quadratus Zone, 7000x, side view.

Fig. 9 Podorhabdus coronadventis (Reinhardt) Reinhardt, UCL-2135-18, Gebel Tarbouli (20), Arkhangelskiella cymbiformis Zone, 3750x, distal view.

Fig. 10 Podorhabdus decorus (Deflandre) Thierstein, UCL-1872-9, Gebel Tarbouli (20), Arkhangelskiella cymbiformis Zone, 4000x, proximal view.

Fig. 11 Podorhabdus decorus (Deflandre) Thierstein, UCL-1872-10 (same specimen), Gebel Tarbouli (20), Arkhangelskiella cymbiformis Zone, 3100x, side view.

Fig. 12 Podorhabdus decorus (Deflandre) Thierstein, UCL-2135-9, Gebel Tarbouli (20), Arkhangelskiella cymbifromis Zone, 5700x, distal view.

Fig. 13 Cretarhabdus conicus Bramlette and Martini, UCL-1919-1, Wadi Mellaha (30), Lithraphidites quadratus Zone, 6900x, distal view.

Fig. 14 Cretarhabdus crenulatus Bramlette and Martini, UCL-1872-3, Gebel Tarbouli (20), Arkhangelskiella cymbiformis Zone, 7000x, distal view.

Fig. 15 Cretarhabdus schizobrachiatus (Gartner) Bukry, UCL-1872-29, Gebel Tarbouli (24), Arkhangelskiella cymbiformis Zone, 4700x, distal view.

PLATE 4

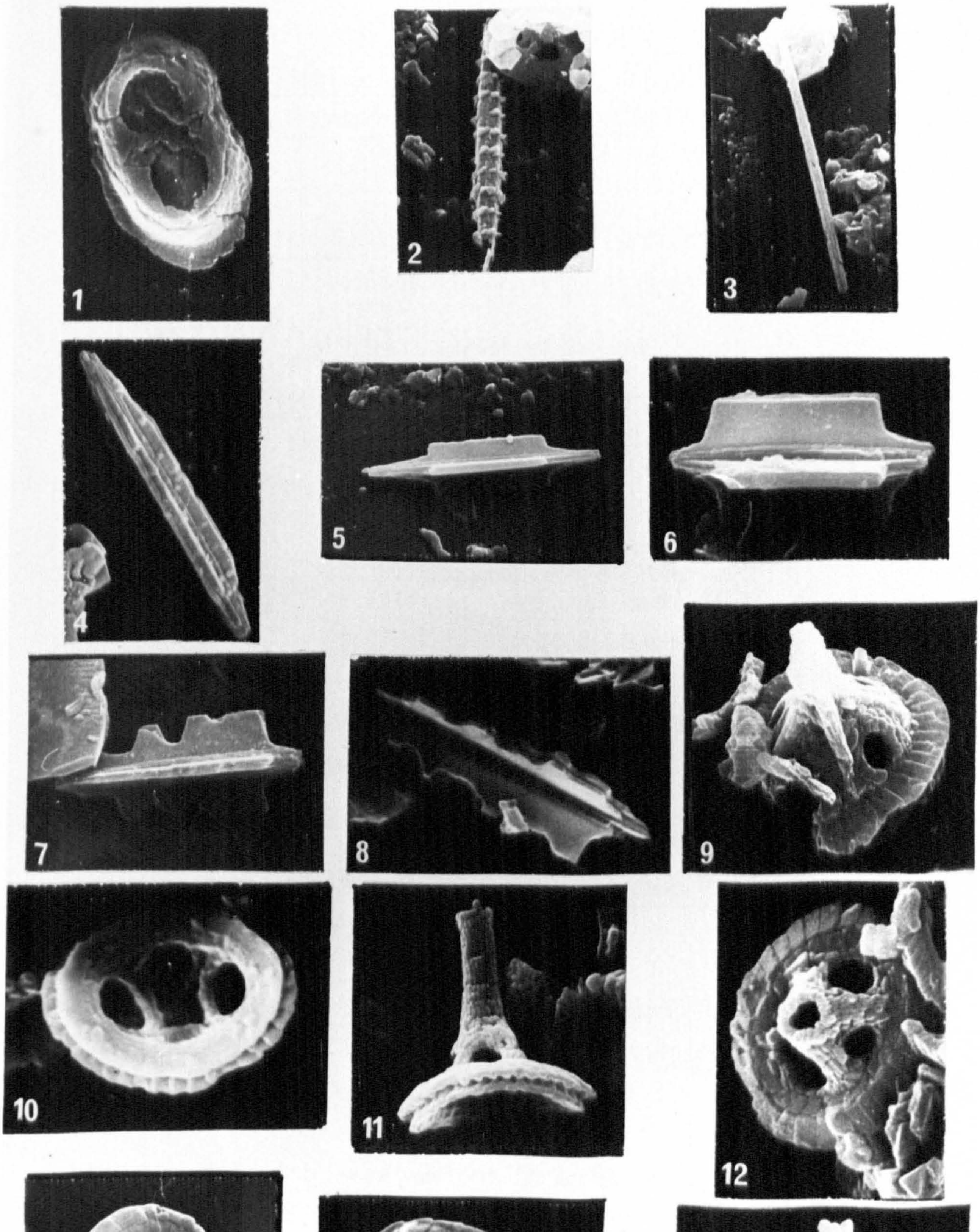


PLATE 5

Fig. 1 Corollithion exgiuum Stradner, UCL-2135-19, Gebel Tarbouli (20), Arkhangelskiella cymbiformis Zone, 10,720x, distal view.

Fig. 2 Corollithion? madagaskarensis Perch-Nielsen, UCL-2135-22, Gebel Tarbouli (20), Arkhangelskiella cymbiformis Zone, 8,500x.

Fig. 3 Corollithion? madagaskarensis Perch-Nielsen, UCL-2135-28, Gebel Tarbouli (20), Arkhangelskiella cymbiformis Zone, 16000x.

Fig. 4 Stephanolithion laffittei Noël, UCL-2130-27, Wadi Mellaha (30), Lithraphidites quadratus Zone, 9500x, distal view.

Fig. 5 Stoverius biarcus (Bukry) Perch-Nielsen, UCL-2135-4, Gebel Tarbouli (20), Arkhangelskiella cymbiformis Zone, 6850x, distal view.

Fig. 6 Stoverius biarcus (Bukry) Perch-Nielsen, UCL-1870-11, Gebel Tarbouli (20), Arkhangelskiella cymbiformis Zone, 6400x, proximal view.

Fig. 7 Cylindralithus duplex Perch-Nielsen, UCL-1872-19, Gebel Tarbouli (24), Arkhangelskiella cymbiformis Zone, 7500x, oblique proximal view.

Fig. 8 Cylindralithus oweinae Perch-Nielsen, UCL-2132-26, Wadi Mellaha (72), Nephrolithus frequens Zone, 5000x, side view.

Fig. 9 Cylindralithus nudus Bukry, UCL-2139-7, Gebel Tarbouli (52), Arkhangelskiella cymbiformis Zone, 7300x, oblique distal view.

Fig. 10 Cylindralithus serratus Bramlette and Martini, UCL-2152-15, Wadi Tarfa (52), Nephrolithus frequens Zone, 6500x, oblique proximal view.

Fig. 11 Cribrocorona gallica (Stradner) Perch-Nielsen, UCL-1925-31, Wadi Mellaha (52), Lithraphidites quadratus Zone, 6000x, side view.

Fig. 12 Quadrum gothicum (Deflandre) Prins and Perch-Nielsen, UCL-1865-13, Gebel Tarbouli (12), Quadrum trifidum Zone, 4600x.

Fig. 13 Cylindralithus stradneri Perch-Nielsen, UCL-1872-27, Gebel Tarbouli (24), Arkhangelskiella cymbiformis Zone, 6500x, side view.

Fig. 14 Micula concava (Stradner) Bukry, UCL-2133-5, Wadi Mellaha (72), Nephrolithus frequens Zone, 3400x.

Fig. 15 Micula sp.A, UCL-2152-6, Wadi Tarfa (52), Nephrolithus frequens Zone, 9380x, oblique view of the convex side.

PLATE 5

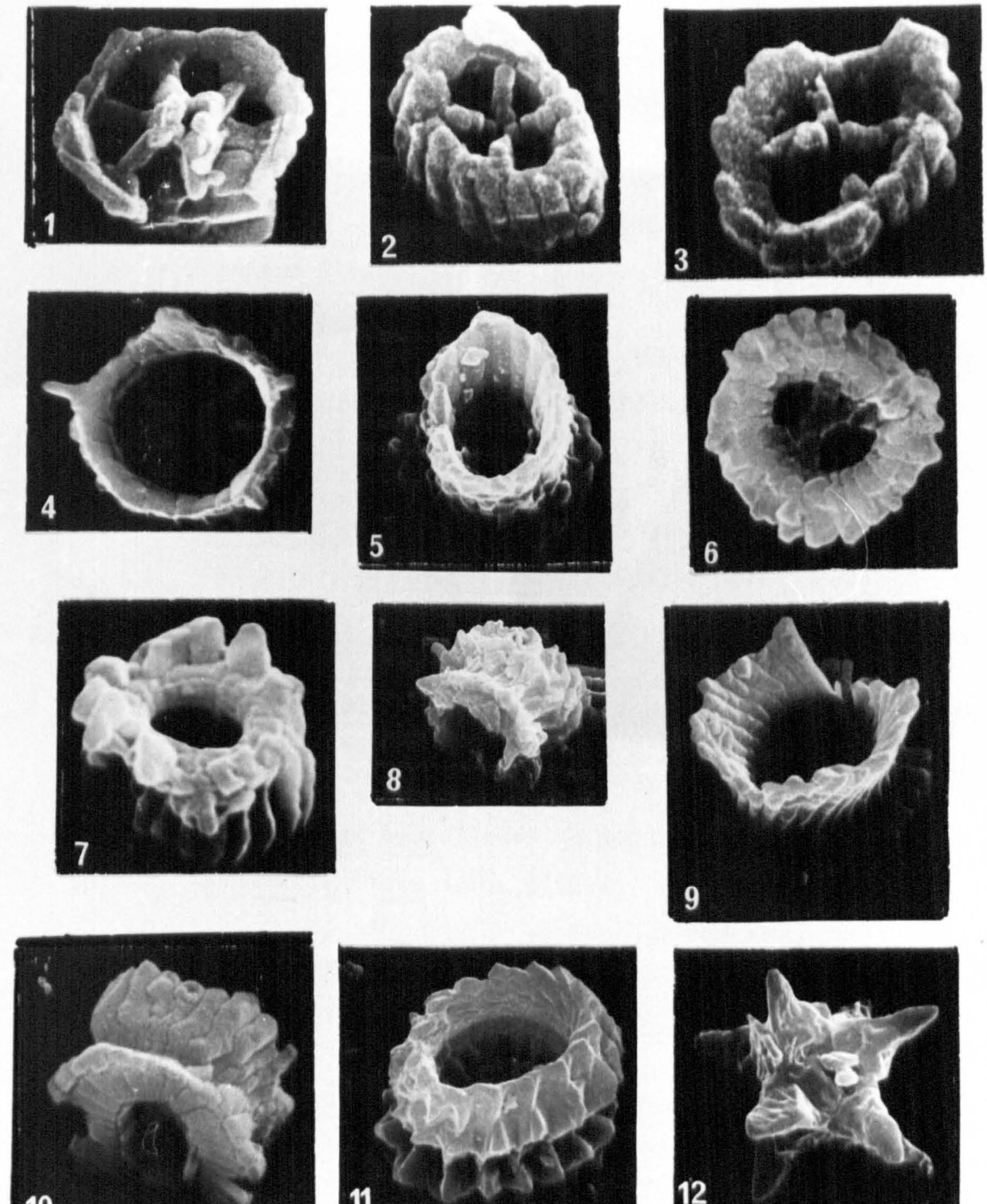


PLATE 6

Fig. 1 Micula murus (Martini) Bukry, UCL-2152-26, Wadi Tarfa (52), Nephrolithus frequens Zone, 8400x, view of the convex side.

Fig. 2 Micula prinsii Perch-Nielsen, UCL-1934-14, Wadi Mellaha (72), Nephrolithus frequens Zone, 4400x, oblique view of the concave side.

Fig. 3 Micula prinsii Perch-Nielsen, UCL-1934-2, Wadi Mellaha (72), Nephrolithus frequens Zone, 6100x, oblique view of the convex side.

Fig. 4 Quadrum gartneri Prins and Perch-Nielsen, UCL-2142-11, Wadi Tarfa (2), Quadrum trifidum Zone, 4400x.

Fig. 5 Quadrum trifidum (Stradner) Prins and Perch-Nielsen, UCL-2136-18, Gebel tarbouli (4), Quadrum trifidum Zone, 5200x.

Fig. 6 Rucinolithus hayi Stover, UCL-2136-3, Gebel Tarbouli (4), Quadrum trifidum Zone, 3900x.

Fig. 7 Thoracosphaera operculata Bramlette and Martini, UCL-2053-24, Gebel Duwi (28), Chiasmolithus danicus Zone, 2,980x.

Fig. 8 Prediscosphaera cretacea (Arkhangelsky) Gartner sub. sp. Cretacea Reinhardt UCL-2131-17 Wadi Mellaha (30), Lithraphidites quadratus Zone, 5600x, oblique distal view.

Fig. 9 Prediscosphaera cretacea lata Bukry, UCL-2142-32, Wadi Tarfa (18), A. cymbiformis Zone, 7800x, distal view.

Fig. 10 Prediscosphaera spinosa (Bramlette and Martini) Gartner, UCL-2131-7 Wadi Mellaha (30), Lithraphidites quadratus Zone, 9400x, oblique distal view.

Fig. 11 *Prediscosphaera honjoi* Bukry, UCL-2142-3, Wadi Tarfa (54), *Nephrolithus frequens* Zone, 11600x, distal view.

Fig. 12 *Prediscosphaera stoveri* (Perch-Nielsen) Shafik and Stradner, UCL-1925-17, Wadi Mellaha (44), *Lithraphidites quadratus* Zone, 10500x, distal view.

Fig. 13 *Lucianorhabdus* cf. *cayeuxii* Deflandre, UCL-2142-20, Wadi Tarfa (4), *Quadrum trifidum* Zone, 7500x, side view.

Fig. 14 *Zygrhablithus bijugatus* (Deflandre) Deflandre, UCL-1903-11, Gebel Tarbouli (60), *Tribrachiatus contortus* Zone, 6140x, side view.

Fig. 15 *Ceratolithoides aculeus* (Stradner) Prins and Sissingh, UCL-1877-22, Gebel Tarbouli (32), *Lithraphidites quadratus* Zone, 7500x, side view.

PLATE 6

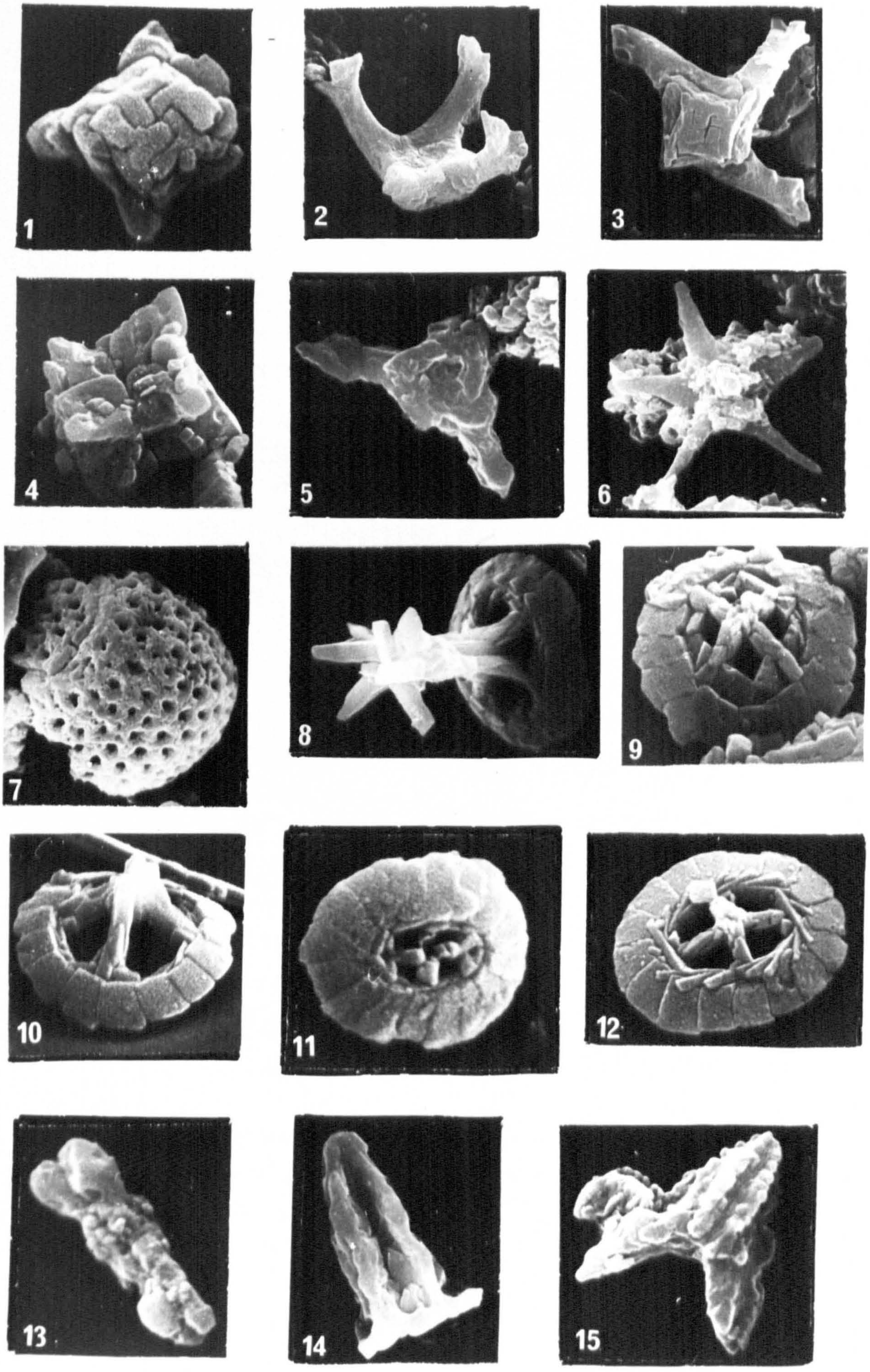


PLATE 7

Fig. 1 *Scapholithus apertus* Hay and Mohler, UCL-1964-35, Gebel Atshan (24), *Discoaster multiradiatus* Zone, 10000x.

Fig. 2 *Rhomboaster bitrifida* Romein, UCL-1892-9, Gebel Tarbouli (56), *Tribrachiatus contortus* Zone, 4200x, side view.

Fig. 3 *Tribrachiatus bramlettei* (Brönnimann and Stradner) Proto Decima et al. UCL-1892-23, Gebel Tarbouli (60), *Tribrachiatus contortus* Zone, 3500x, side view.

Fig. 4 *Tribrachiatus contortus* (Stradner) Bukry, UCL-1903-25, Gebel Tarbouli (60), *Tribrachiatus contortus* Zone, 3700x.

Fig. 5 *Cruciplacolithus primus* Perch-Nielsen, UCL-2085-23, Gebel Duwi (102), *Fasciculithus tympaniformis* Zone, 4800x, distal view.

Fig. 6 *Cruciplacolithus tenuis* (Stradner) Hay and Mohler, UCL-2053-35, Gebel Duwi (58), *Ellipsolithus macellus* Zone, 5000x, distal view.

Fig. 7 *Cruciplacolithus frequens* (Perch-Nielsen) Romein, UCL-2037-15, Wadi Tarfa (61), *Fasciculithus tympaniformis* Zone, 4600x, distal view.

Fig. 8 *Cruciplacolithus edwardsii* Romein, UCL-2053-27, Gebel Duwi (58), *Ellipsolithus macellus* Zone, 4800x, distal view.

Fig. 9 *Campylosphaera dela* (Bramlette and Sullivan) Hay and Mohler, UCL-1903-12, Gebel Tarbouli (60), *Tribrachiatus contortus* Zone, 6900x, proximal view.

Fig. 10 *Ericsonia cava* (Hay and Mohler) Perch-Nielsen, UCL-1951-8, Gebel Atshan (12), *Chiasmolithus danicus* Zone, 7500x, distal view.

Fig. 11 Ericsonia subpertusa Hay and Mohler, UCL-2053-6, Gebel Duwi (28), Chiasmolithus danicus Zone, 6750x, distal view.

Fig. 12 Ericsonia eopelagica (Bramlette and Riedel) Romein , UCL-2085-6, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 4700x, distal view.

Fig. 13 Ericsonia robusta (Bramlette and Sullivan) Perch-Nielsen, UCL-2080-1, Wadi Mellaha (82), Discoaster multiradiatus Zone, 7500x, distal view.

Fig. 14 Ericsonia sp. A, UCL-2062-3, Gebel Atshan (20), Discoaster multiradiatus Zone, 11900x, distal view.

Fig. 15 Ericsonia sp. A., UCL-2045-27, Gebel Um El Ghanayem (44), Discoaster multiradiatus Zone, 9500, distal view.

PLATE 7

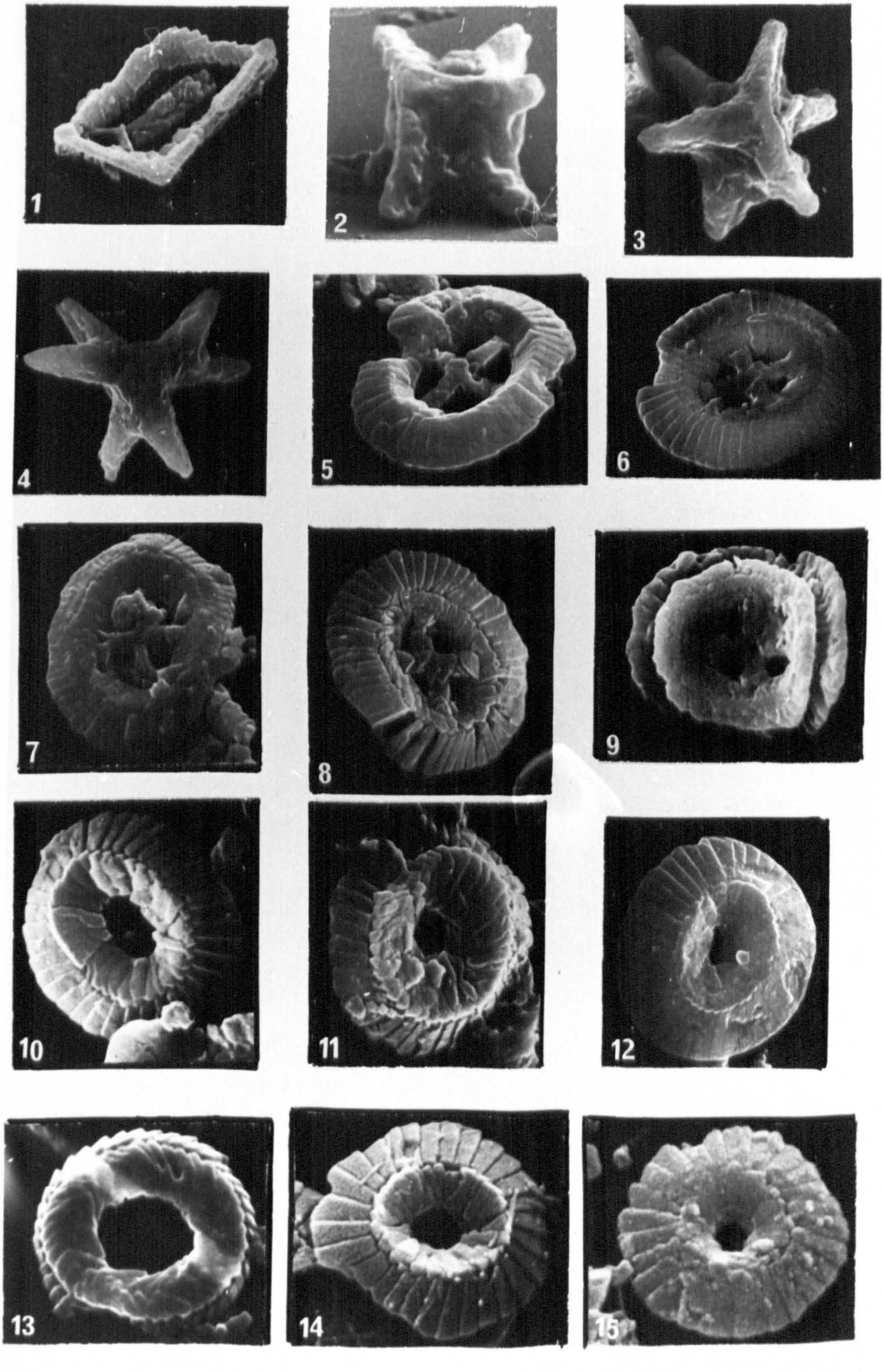


PLATE 8

Fig. 1 Chiasmolithus danicus (Brotzen) Hay and Mohler, UCL-2053-18, Gebel Duwi (28), Chiasmolithus danicus Zone, 6000x, distal view.

Fig. 2 Chiasmolithus consuetus (Bramlette and Sullivan) Hay and Mohler, UCL-2063-13, Gebel Atshan (20), Discoaster multiradiatus Zone, 4600x, distal view.

Fig. 3 Chiasmolithus californicus (Sullivan) Hay and Mohler, UCL-1882-10, Gebel Tarbouli (56), Tribrachiatus contortus Zone, 3750x, distal view.

Fig. 4 Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler, UCL-1972-33, Gebel Atshan (26), Discoaster multiradiatus Zone, 4000x, proximal view.

Fig. 5 Chiasmolithus eograndis Perch-Nielsen, UCL-2084-16, Gebel Tarbouli (60), Tribrachiatus contortus Zone, 3600x, proximal view.

Fig. 6 Prinsius dimorphosus (Perch-Nielsen) Perch-Nielsen, UCL-1951-12, Gebel Atshan (12), Chiasmolithus danicus Zone, 12500x, distal view.

Fig. 7 Prinsius martinii (Perch-Nielsen) Haq, UCL-2042-10, Wadi Tarfa (62), Discoaster multiradiatus Zone, 10500x, distal view.

Fig. 8 Prinsius bisulcus (Stradner) Hay and Mohler, UCL-1995-5, Gebel Atshan (18), Fasciculithus tympaniformis Zone, 9400x, distal view.

Fig. 9 Toweius pertusus (Sullivan) Romein, UCL-1964-22, Gebel Atshan (22), Discoaster multiradiatus Zone, 9600x, distal view.

Fig. 10 *Toweius eminens* (Bramlette and Sullivan) Gartner, UCL-1964-12, Gebel Atshan (22), *Discoaster multiradiatus* Zone, 7000x, oblique distal view.

Fig. 11 *Toweius tovae* Perch-Nielsen, UCL-1964-2, Gebel Atshan (22), *Discoaster multiradiatus* Zone, 6900x, distal view.

Fig. 12 *Sphenolithus primus* Perch-Nielsen, UCL-2081-1, Wadi Mellaha (90), *Tribrachiatus contortus* Zone, 4600x, side view.

Fig. 13 *Sphenolithus moriformis* (Brönnimann and Stradner) Bramlette and Wilcoxon, UCL-2063-27, Gebel Atshan (20), *Discoaster multiradiatus* Zone, 6000x, side view.

Fig. 14 *Sphenolithus editus* Perch-Nielsen, UCL-1903-7, Gebel Tarbouli (60), *Tribrachiatus contortus* Zone, 6300x, side view.

Fig. 15 *Fasciculithus gelelii* n. sp., paratype, UCL-2062-2, Gebel Atshan (20), *Fasciculithus tympaniformis* Zone, 2300x, side view.

PLATE 8

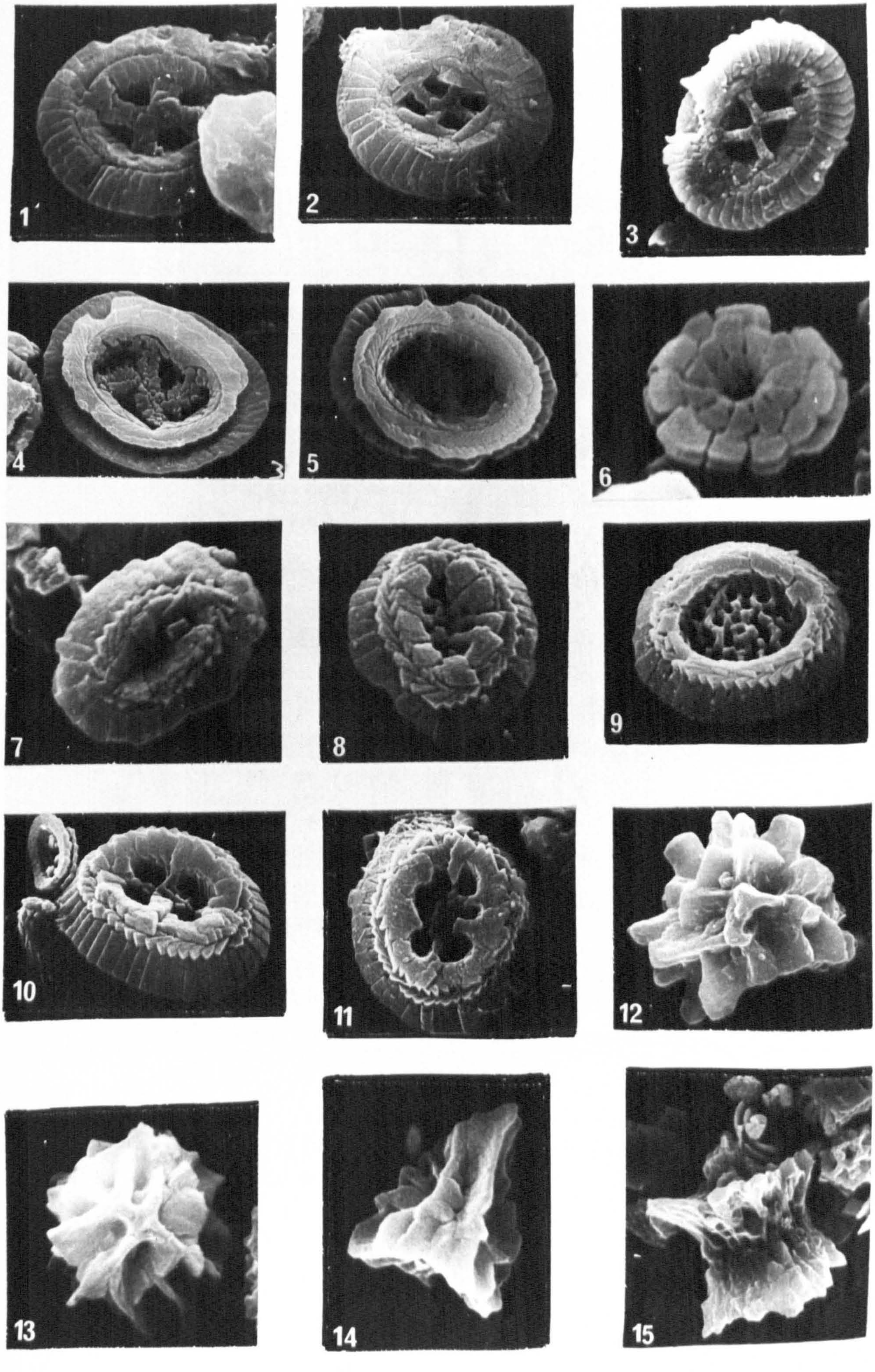


PLATE 9

Fig. 1 Fasciculithus ragaae n. sp., paratype, UCL-1995-6, Gebel Atshan (18), Fasciculithus tympaniformis Zone, 8000x, oblique view of the "convex" face.

Fig. 2 Fasciculithus ragaae n. sp., holotype, UCL-1995-2, Gebel Atshan (18), Fasciculithus tympaniformis Zone, 7800x, side view.

Fig. 3 Fasciculithus janii Perch-Nielsen, UCL-2080-7, Wadi Mellaha (80), Fasciculithus tympaniformis Zone, 4300x, side view.

Fig. 4 Fasciculithus tympaniformis Hay and Mohler, UCL-2042-20, Wadi Tarfa (68), Discoaster multiradiatus Zone, 5000x, oblique view of the convex face.

Fig. 5 Fasciculithus bobii Perch-Nielsen, UCL-2063-1, Gebel Atshan (20), Discoaster multiradiatus Zone, 5300x, side view.

Fig. 6 Fasciculithus bobii Perch-Nielsen, UCL-1964-14, Gebel Atshan (22), Discoaster multiradiatus Zone, 5000x, oblique view of the concave face.

Fig. 7 Fasciculithus billii Perch-Nielsen, UCL-2068-19, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 4680x, oblique view of the concave face.

Fig. 8 Fasciculithus tonii Perch-Nielsen, UCL-2045-6, Gebel Um El Ghanayem (40), Discoaster multiradiatus Zone, 2100x, side view.

Fig. 9 Fasciculithus involutus Bramlette and Sullivan, UCL-2063-21, Gebel Atshan (20), Discoaster multiradiatus Zone, 5000x, side view.

Fig. 10 Fasciculithus schaubi Hay and Mohler, UCL-2076-30, Gebel Atshan (20), Discoaster multiradiatus Zone, 6800x, side view.

Fig. 11 Fasciculithus gelelii n. sp., UCL-2068-20, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 4000x, oblique view of the "convex" face.

Fig. 12 Fasciculithus gelelii n. sp., holotype, UCL-1964-23, Gebel Atshan (22), Discoaster multiradiatus Zone, 2850x, side view.

Fig. 13 Bomolithus elegans Roth, UCL-2069-2, Gebel Duwi (108), Fasciculithus tympaniformis Zone, 4500x, oblique view of the convex face.

Fig. 14 Bomolithus megastypus (Bramlette and Sullivan) n. comb., UCL-2085-7, Gebel Duwi (107), Fasciculithus tympaniformis Zone, 4380x, view of the convex face.

Fig. 15 Bomolithus megastypus (Bramlette and Sullivan) n. comb., UCL-2085-1, Gebel Duwi (107), Fasciculithus tympaniformis Zone, 6000x, oblique view of the concave face.

PLATE 9

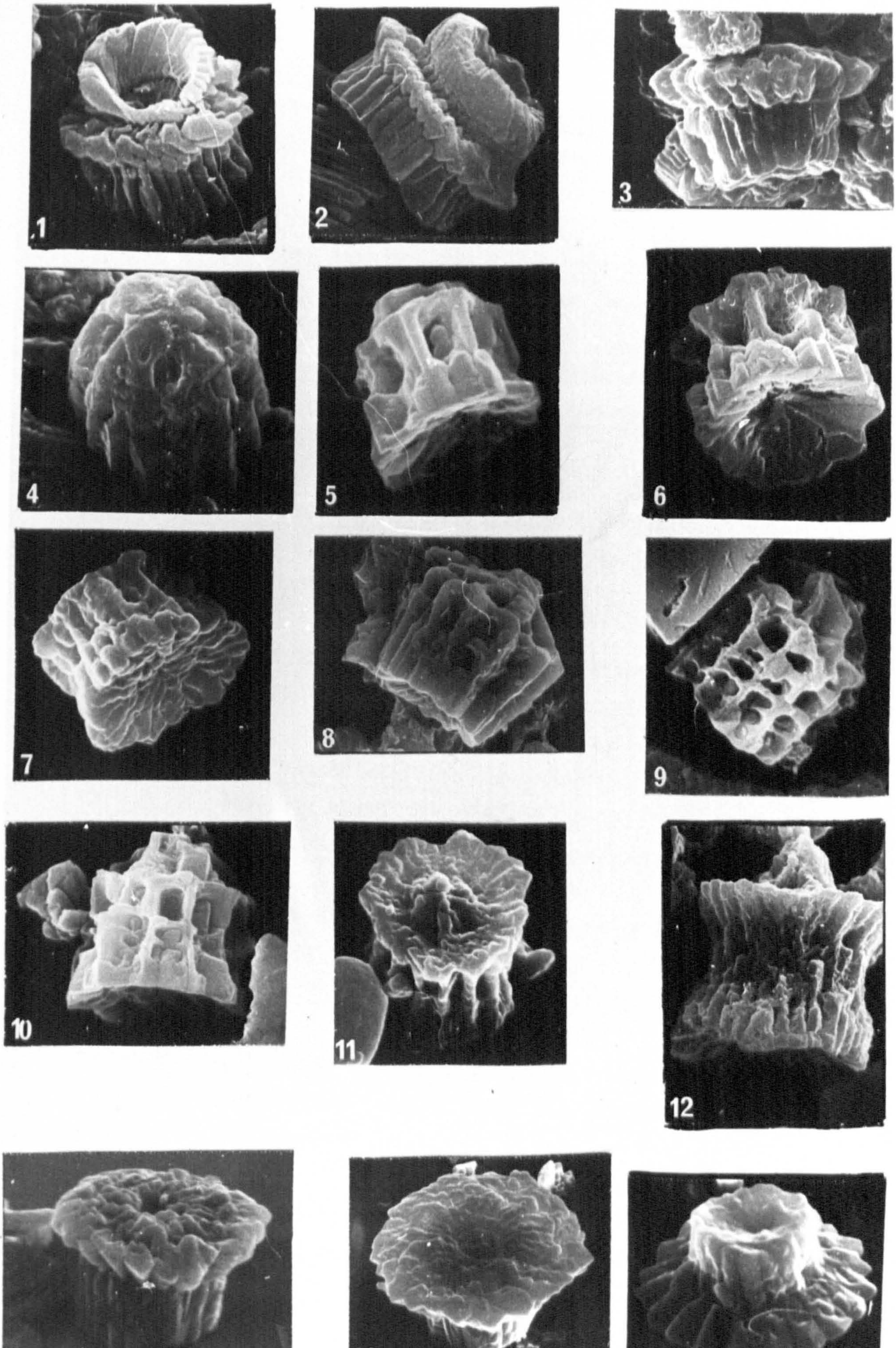


PLATE 10

Fig. 1 Bomolithus cantabriae (Perch-Nielsen) n. comb., UCL-2077-7, Gebel Atshan (20), Discoaster multiradiatus Zone, 3200x, oblique view of the concave face.

Fig. 2 Bomolithus sp., UCL-02077-4, Gebel Atshan (20), Discoaster multiradiatus Zone, 2500x, oblique view of the concave face.

Fig. 3 Heliolithus riedelii Bramlette and Sullivan, UCL-2077-14, Gebel Atshan (20), Discoaster multiradiatus Zone, 7500x, side view.

Fig. 4 Discoaster drieveri (Bukry and Percival) Romein, UCL-2085-26, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 7200x, oblique view of the inferior face.

Fig. 5 Discoaster atefii n. sp., holotype, UCL-2085-27, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 3900x, side view.

Fig. 6 Discoaster atefii n. sp., holotype (specimen fig. 5 in oblique view), UCL-2085-28, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 3900x, oblique view of the superior face.

Fig. 7 Discoaster atefii n. sp., holotype (oblique view of the superior face of specimen fig. 5), UCL-2085-29, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 3900x.

Fig. 8 Discoaster duwiensis n. sp., holotype, UCL-2068-14, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 6400x, view of the superior face.

Fig. 9 Discoaster duwiensis n. sp., holotype (specimen fig. 8 in side view), UCL-2068-15, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 6250x, side view.

Fig. 10 Discoaster sp., UCL-2042-27, Wadi Tarfa (68), Discoaster multiradiatus Zone, 6000x, oblique view of the superior face.

Fig. 11 Discoaster mohleri Bukry and Percival, UCL-1972-15, Gebel Atshan (26), Discoaster multiradiatus Zone, 6000x, view of the superior face.

Fig. 12 Discoaster mediosus Bramlette and Sullivan, UCL-1995-14, Wadi Mellaha (86), Tribrachiatus contortus Zone, 3700x, view of the inferior face.

Fig. 13 Discoaster nobilis Martini, UCL-2051-7, Gebel Um El Ghanayem (40), Discoaster multiradiatus Zone, 3000x, view of the superior face.

Fig. 14 Discoaster amrii n. sp., holotype, UCL-2076-29, Gebel Atshan (26), Discoaster multiradiatus Zone, 6200x, view of the superior face.

Fig. 15 Discoaster amrii n. sp., paratype, UCL-1964-10, Gebel Atshan (22), Discoaster multiradiatus Zone, 6500x, view of the superior face.

PLATE 10

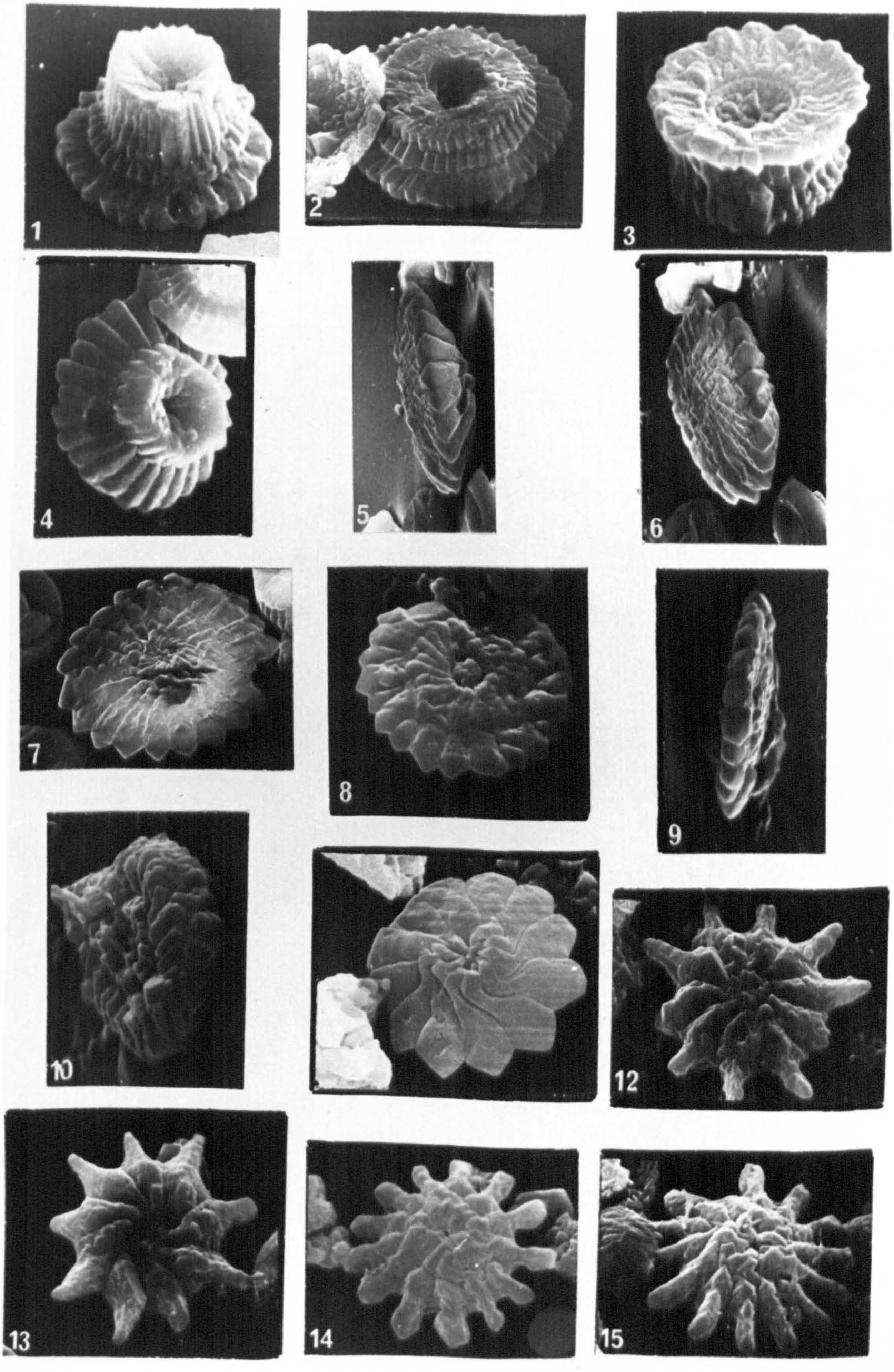


PLATE 11

Fig. 1 Discoaster binodosus Martini, UCL-1903-2, Gebel Tarbouli (60), Tribrachiatus contortus Zone, 2900x, view of the inferior face.

Fig. 2 Discoaster binodosus Martini, UCL-1903-1, Gebel Tarbouli (60), Tribrachiatus contortus Zone, 3300x, view of the superior face.

Fig. 3 Discoaster multiradiatus Bramlette and Riedel, UCL-1995-10, Wadi Mellaha (86), Tribrachiatus contortus Zone, 2900x, view of the superior face.

Fig. 4 Discoaster multiradiatus Bramlette and Riedel, UCL-1964-17, Gebel Atshan (22), Discoaster multiradiatus Zone, 5400x, view of the superior face.

Fig. 5 Discoaster diastypus Bramlette and Sullivan, UCL-2080-17, Wadi Mellaha (86), Tribrachiatus contortus Zone, 2100x.

Fig. 6 Discoaster diastypus Bramlette and Sullivan, UCL-2084-6, Gebel Tarbouli (60), Tribrachiatus contortus Zone, 2300x.

Fig. 7 Discoaster salisburgensis Stradner, UCL-2073-3, Gebel Duwi (139), Discoaster multiradiatus Zone, 4000x.

Fig. 8 Discoaster salisburgensis Stradner, UCL-2073-5, Gebel Duwi (139), Discoaster multiradiatus Zone, 3400x.

Fig. 9 Discoaster mahmoudii Perch-Nielsen, UCL-1882-26, Gebel Tarbouli (56), Tribrachiatus contortus Zone, 3700x.

Fig. 10 Discoaster mahmoudii Perch-Nielsen, UCL-1882-7, Gebel Tarbouli (56), Tribrachiatus contortus Zone, 3300x.

Fig. 11 Discoaster okadai Bukry, UCL-1972-10, Gebel Atshan (26), Discoaster multiradiatus Zone, 4500x.

Fig. 12 Pontosphaera versa (Bramlette and Sullivan) Perch-Nielsen, UCL-2081-8, Wadi Mellaha (90), Tribrachiatus contortus Zone, 6200x, distal view.

Fig. 13 Pontosphaera exilis (Bramlette and Sullivan) Romein, UCL-2084-5, Gebel Tarbouli (60), Tribrachiatus contortus Zone, 4500x, distal view.

Fig. 14 Ellipsolithus macellus (Bramlette and Sullivan) Sullivan, UCL-2073-27, Gebel Atshan (24), Discoaster multiradiatus Zone, 3300x, proximal view.

Fig. 15 Ellipsolithus distichus (Bramlette and Sullivan) Sullivan, UCL-2085-35, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 5700x, proximal view.

PLATE 11

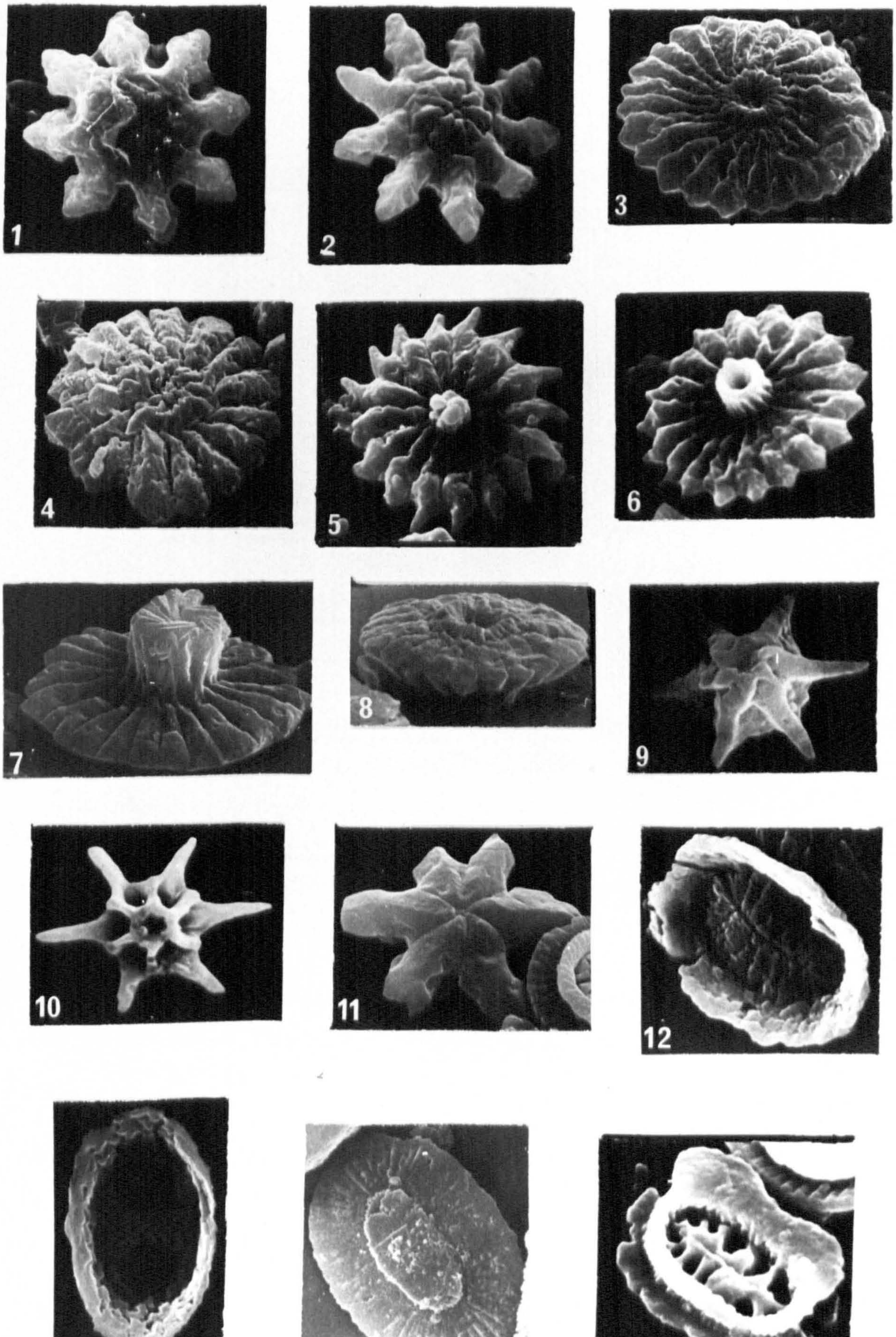


PLATE 12

Fig. 1 Ellipsolithus parallelus Perch-Nielsen, UCL-2277-7, Gebel Tarbouli (30), Lithraphidites quadratus Zone, 2600x, phase contrast.

Fig. 2 Helicolithus trabeculatus (Górka) Verbeek, UCL-2277-20, Gebel Tarbouli (52), Nephrolithus frequens Zone, 3500x, phase contrast.

Fig. 3 Discolithina spiralis (Pienaar) Verbeek, UCL-2277-13, Gebel Tarbouli (30), Lithraphidites quadratus Zone, 1800x, cross nicols.

Fig. 4 Nephrolithus frequens Górka, UCL-2277-14, Gebel Tarbouli (36), Nephrolithus frequens Zone, 2800x, phase contrast.

Fig. 5 Micula prinsii Perch-Nielsen, UCL-2278-9, Wadi Mellaha (72), Nephrolithus frequens Zone, 2900x, cross nicols.

Fig. 6 Tranolithus phacelosus Stover, Gebel Tarbouli (14), Quadrum trifidum Zone, UCL-2277-1, 2700x, phase contrast.

Fig. 7 Glaukolithus compactus (Bukry) Perch-Nielsen, UCL-2278-5, Gebel Tarbouli (12), Quadrum trifidum Zone, 1600x, cross nicols.

Fig. 8 Glaukolithus diplogrammus (Deflandre) Reinhardt, UCL-2277-3, Gebel Tarbouli (14), Quadrum trifidum Zone, 3500x, cross nicols.

Fig. 9 Zeugrhabdotus embergeri (Noël) Perch-Nielsen, UCL-1861-2, Gebel Tarbouli (12), Quadrum trifidum Zone, 1700x, phase contrast.

Fig. 10 Cylindralithus nudus Bukry, UCL-2281-24, Gebel Tarbouli (52), Nephrolithus frequens Zone, 3100x, phase contrast.

Fig. 11 Cylindralithus oweinae Perch-Nielsen, UCL-2281-35, Wadi Mellaha (52), Lithraphidites quadratus Zone, 2700x, phase contrast.

Fig. 12 Cylindralithus sp.1 UCL-2281-33, Wadi Mellaha (52), Lithraphidites quadratus Zone, 2300x, phase contrast.

Fig. 13 Cylindralithus duplex Perch-Nielsen, UCL-2283-5, Gebel Tarbouli (8), Quadrum trifidum Zone, 3000x, phase contrast.

Fig. 14 Stoverius biarcus (Bukry) Perch-Nielsen, UCL-1861-16, Gebel Tarbouli (16), Quadrum trifidum Zone, 2400x, phase contrast.

Fig. 15 Quadrum trifidum (Stradner) Prins and Perch-Nielsen, UCL-1861-6, Gebel Tarbouli (12), Quadrum trifidum Zone, 2100x, phase contrast.

Fig. 16 Quadrum gothicum (Deflandre) Prins and Perch-Nielsen, UCL-1861-4, Gebel Tarbouli (12), Quadrum trifidum Zone, 2100x, phase contrast.

Fig. 17 Quadrum sissinghii Perch-Nielsen, UCL-1856-28, Gebel Tarbouli (10), Quadrum trifidum Zone, 2000x, phase contrast.

Fig. 18 Gartnerago obliquum (Stradner) Reinhardt, UCL-2278-1, Gebel Tarbouli (8), Quadrum trifidum Zone, 2100x, phase contrast.

Fig. 19 Reinhardtites levis Prins and Sissingh, UCL-2277-32, Gebel Tarbouli (8), Quadrum trifidum Zone, 2300x, cross nicols.

Fig. 20 Broinsonia parca (Stradner) Bukry, UCL-1856-19, Gebel Tarbouli (8), Quadrum trifidum Zone, 1700x, phase contrast.

PLATE 12

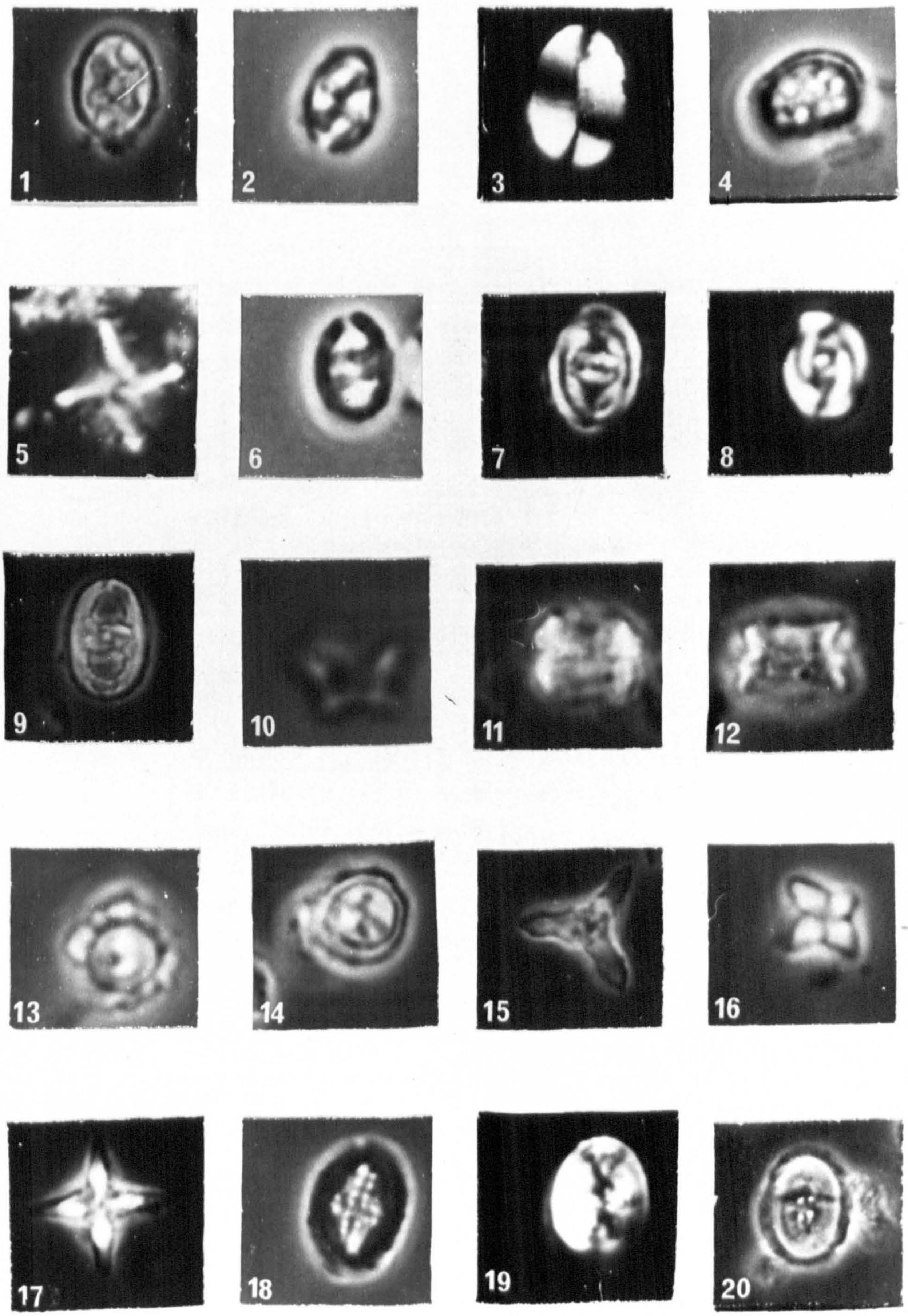


PLATE 13

Fig. 1 *Cruciplacolithus primus* Perch-Nielsen, UCL-2278-18, Gebel Atshan (13), *Chiasmolithus danicus* Zone, 2300x, phase contrast.

Fig. 2 *Cruciplacolithus tenuis* (Stradner) Hay and Mohler, UCL-2278-17, Gebel Atshan (12), *Chiasmolithus danicus* Zone, 1900x, phase contrast.

Fig. 3 *Cruciplacolithus frequens* (Perch-Nielsen) Romein, UCL-2279-9, Gebel Atshan (24), *Discoaster multiradiatus* Zone, 1800x, phase contrast.

Fig. 4 *Ericsonia cava* (Hay and Mohler) Perch-Nielsen, UCL-2278-15, Gebel Atshan (12), *Chiasmolithus danicus* Zone, 3000x, phase contrast.

Fig. 5 *Ericsonia subpertusa* Hay and Mohler, UCL-2278-21, Gebel Atshan (13), *Chiasmolithus danicus* Zone, 3000x, phase contrast.

Fig. 6 *Ericsonia eopelagica* (Bramlette and Riedel) Romein , UCL-2278-29, Gebel Atshan (20), *Discoaster multiradiatus* Zone, 2900x, phase contrast.

Fig. 7 *Ericsonia* sp.A. UCL-2281-21, Gebel Um El Ghanayem (44), *Discoaster multiradiatus* Zone, 3500x, phase contrast.

Fig. 8 *Fasciculithus gelelii* n. sp., UCL-2279-1, Gebel Atshan (20), *Discoaster multiradiatus* Zone, 1600x, side view, cross nicols.

Fig. 9 *Fasciculithus billi* Perch-Nielsen, UCL-2279-5, Gebel Atshan (20), *Discoaster multiradiatus* Zone, 3600x, side view, cross nicols.

Fig. 10 Fasciculithus tympaniformis Hay and Mohler, UCL-2279-4, Gebel Atshan (20), Discoaster multiradiatus Zone, 2600x, side view, cross nicols.

Fig. 11 Fasciculithus bobii Perch-Nielsen, UCL-2279-3, Gebel Atshan (20), Discoaster multiradiatus Zone, 2300x, side view, cross nicols.

Fig. 12 Fasciculithus ragaae n. sp., UCL-2278-22, Gebel Atshan (18), Fasciculithus tympaniformis Zone, 2800x, side view, phase contrast.

Fig. 13 Bomolithus elegans Roth, UCL-2281-11, Gebel Duwi (110), Fasciculithus tympaniformis Zone, 3000x side view, cross nicols.

Fig. 14 Bomolithus cantabriae (Perch-Nielsen) n. comb., UCL-2278-31, Gebel Atshan (20), Discoaster multiradiatus Zone, 2800x, side view, cross nicols.

Fig. 15 Chiasmolithus consuetus Bramlette and Sullivan, UCL-2279-29, Gebel Tarbouli (56), Tribrachiatus contortus Zone, 3100x, phase contraxt.

Fig. 16 Discoaster duwiensis n. sp., UCL-2281-4, Gebel Duwi (102), Fasciculithus tympaniformis Zone, 2200x, view of the superior face, phase contrast.

Fig. 17 Discoaster multiradiatus Bramlette and Riedel, UCL-2279-32, Wadi Mellaha (82), Discoaster multiradiatus Zone, 1400x, view of the superior face, phase contrast.

Fig. 18 Discoaster nobilis Martini, UCL-2279-16, Gebel Duwi (139), Discoaster multiradiatus Zone, 2100x, view of the superior face, phase contrast.

PLATE 13

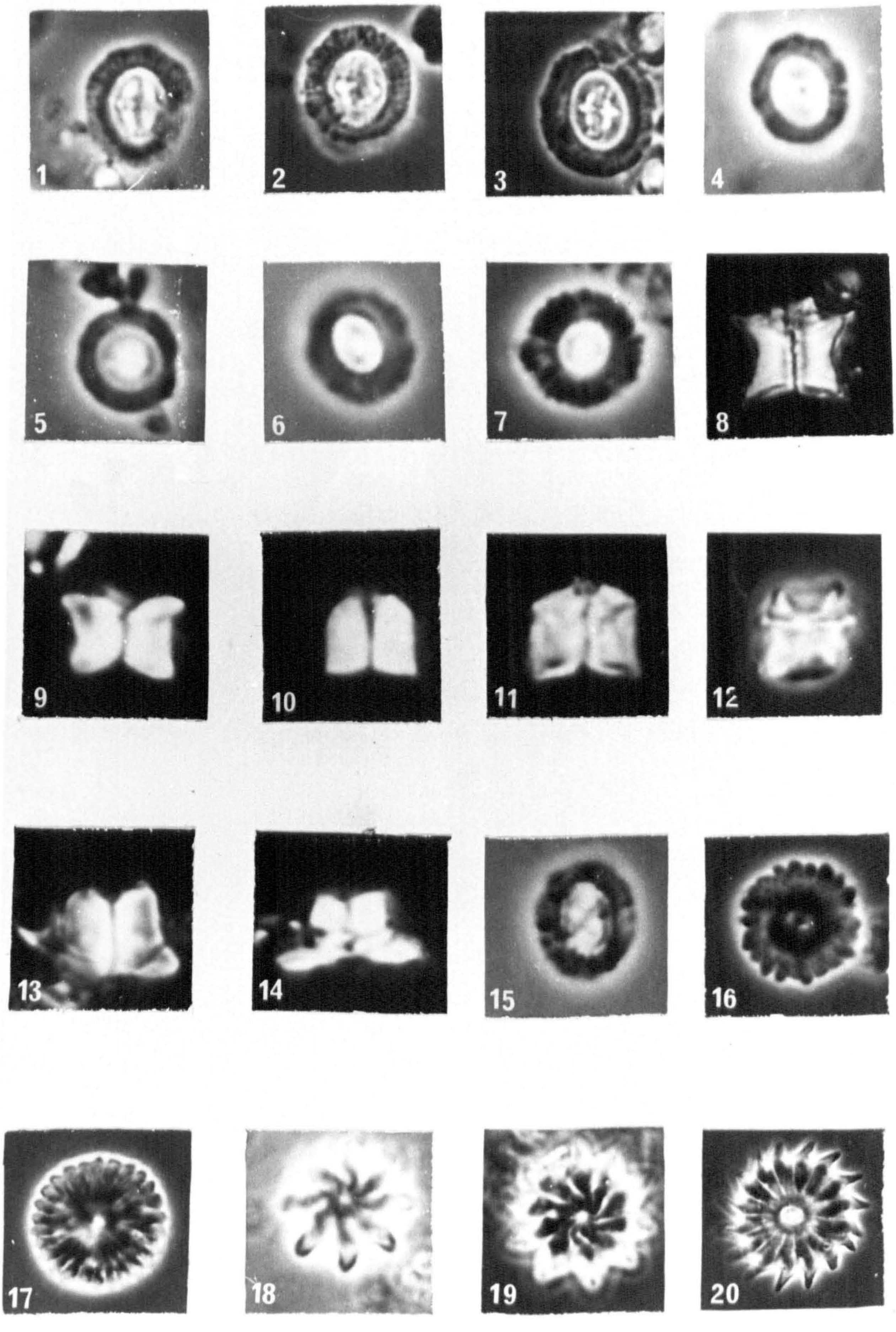
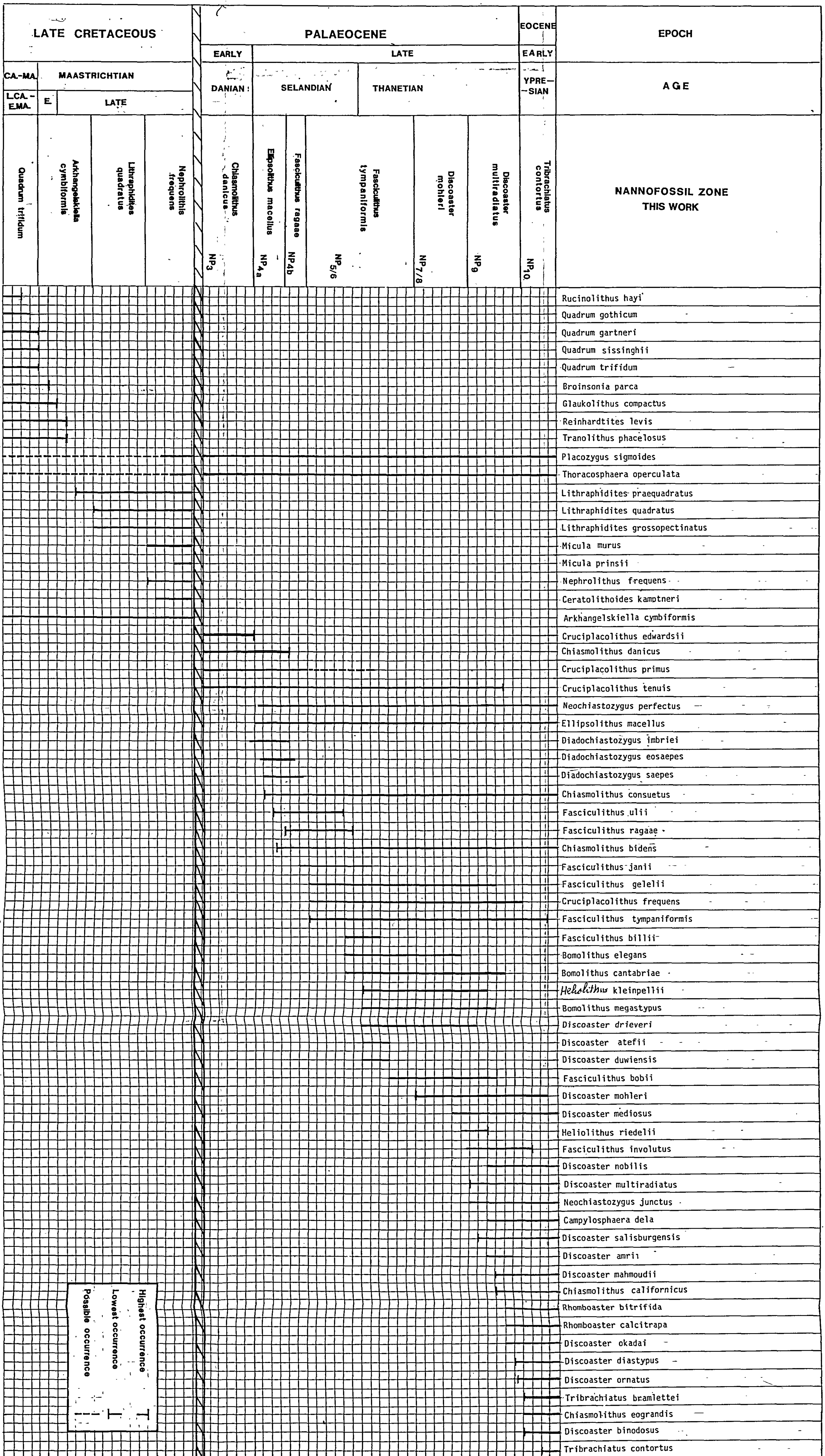


Table 1-DISTRIBUTION OF BIOSTRATIGRAPHICALLY IMPORTANT UPPER CRETACEOUS-LOWER TERTIARY CALCAREOUS NANNOFOSSILS IN Egypt



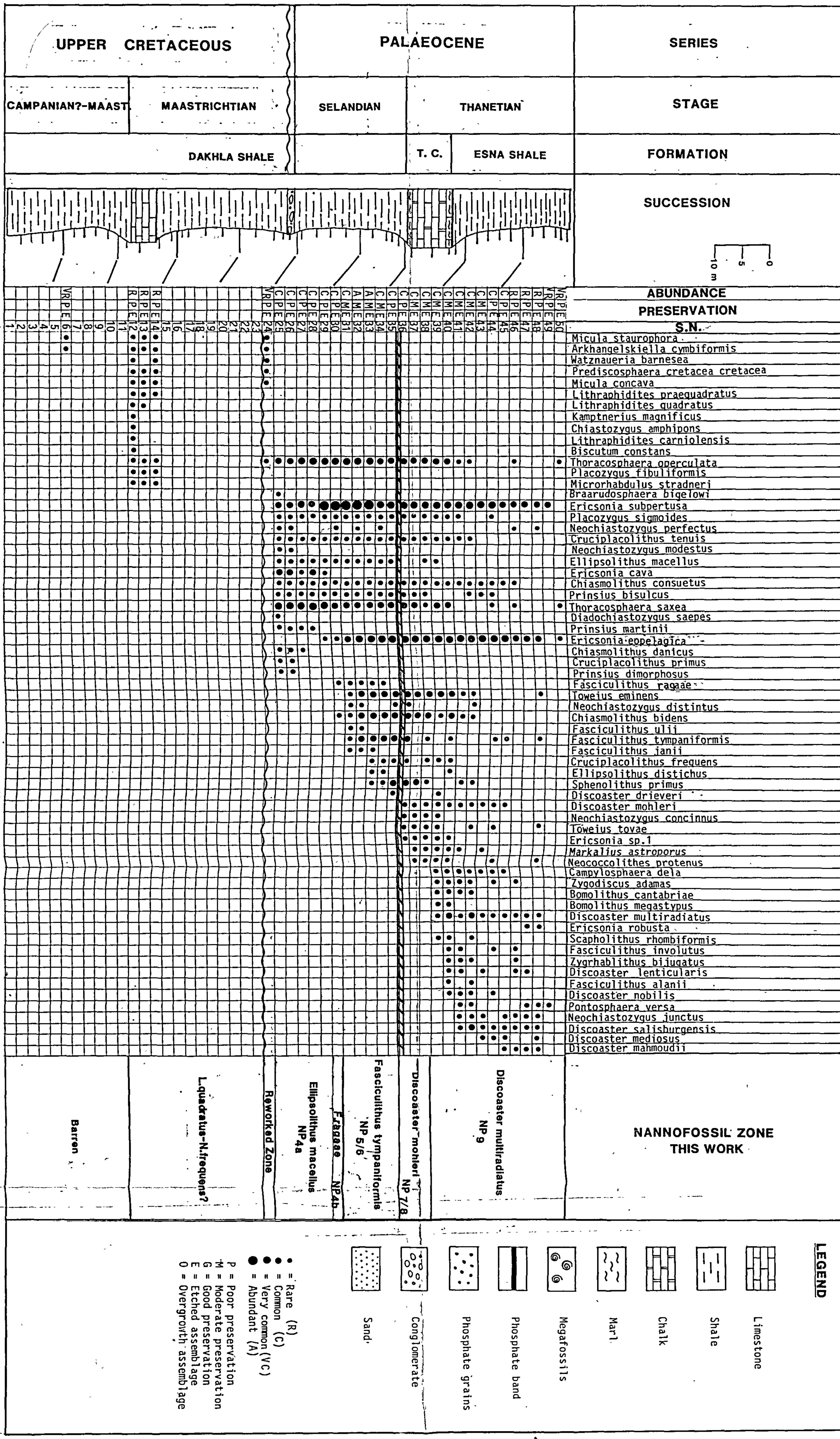


Fig. 19 - SECTION UM EL GHANAYEM ; LITHOLOGY, DISTRIBUTION OF SPECIES AND BIOZONATION

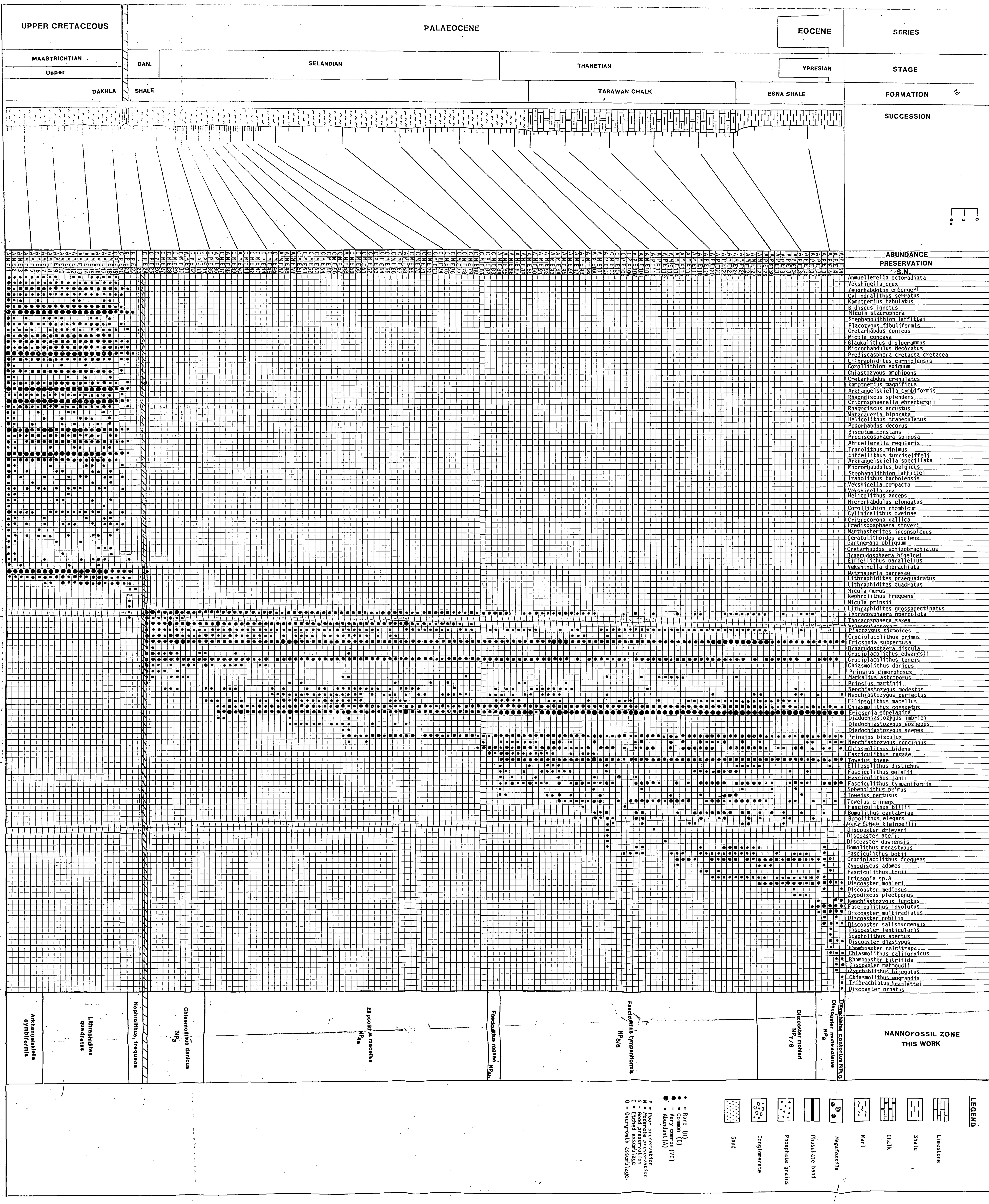


Fig.20- SECTION GEBEL DUWI : LITHOLOGY, DISTRIBUTION OF SPECIES AND BIOZONATION

Fig.21- SECTION GEBEL ATSHAN, LITHOLOGY, DISTRIBUTION OF SPECIES AND BIOZONATION

Fig.22-SECTION GEBEL TARBOUL; LITHOLOGY, DISTRIBUTION OF SPECIES AND BIOZONATION

Fig.23- SECTION WADI MELLAHA, LITHOLOGY, DISTRIBUTION OF SPECIES AND BIOZONATION

Fig.24-SECTION WADI TARFA : LITHOLOGY, DISTRIBUTION OF SPECIES AND BIOZONATION